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ERRATA

Through a misunderstanding in proof reading, the headings for Tables 10, 11, and 12 on pages 678 and 679 of the October, 1924, issue of the JOURNAL were interchanged. The corrected headings are printed below, and it is suggested that all those who care to do so paste these over the incorrect headings as indicated.

TABLE 10—*Relative yields from large and small seeds when planted in equal weights, at a rate normal for the large seeds.*

TABLE 11—*Relative yields from unselected and large and small or heavy and light seeds as separated by a fanning mill and planted in equal volumes.*

TABLE 12—*Relative yields from large and small or heavy and light seeds as separated by a fanning mill and planted in equal volumes.*

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REPORT OF COMMITTEE ON STANDARDIZATION OF FIELD EXPERIMENTS[1]

The question of standardizing methods of conducting field experiments has been carefully studied by this Committee for several years. Information concerning the practices of the majority of the experiment station workers in this country has been collected. Wherever experiments in methods have been conducted the results have been analyzed. With the data at hand, the Committee now feels that the Society should make a start towards defining and adopting certain standards for locating, laying out and conducting the ordinary kinds of field experiments. In certain features of field experimental work, there can be no question of the desirability of all workers adopting the same methods of procedure. In other features, there are doubtless good reasons for variation, and considerable latitude must be allowed. The great variety of conditions under which field experimental work must be done makes it impossible, in certain respects, to lay down anything but very general rules. Nevertheless, certain guiding principles can be set down for making such work more uniform and the results more accurate.

It is not the expectation of the Committee that the adoption of certain standards at this time should preclude further investigations in methods or hinder progress in the development of better methods. It should rather stimulate further study, with the understanding that the standards and rules now adopted are open to revision as better methods are devised.

RECOMMENDED STANDARDS FOR FIELD PLAT EXPERIMENTS IN SOIL FERTILITY

Location of Experiments.—Soil fertility experiments should be located with reference to soil types. The location should be representative of the type of soil to which the results of the experiments are to be

[1]Presented at the annual meeting of the Society held in Chicago, November 12, 1923, by the chairman of the Committee. Separate reprints of this report may be obtained from the secretary of the Society.

applied. Only one type of soil should be represented in any one experiment.

Uniformity of Soil.—The uniformity of any piece of land for experimental purposes should be ascertained before beginning experiments. A soil profile to the depth of three feet is highly desirable for each series of plots. If the history of the land as to system of cropping and soil treatment for several years back is not known, it should be tested by a uniform system of cropping without soil treatment through one or more years until its suitability for the purpose is established. Before soil treatment experiments are begun, representative samples of the soil and subsoil should be carefully taken for such analyses as it may be desired to have for future reference.

Topography.—For all ordinary field experiments, the land should be reasonably level and slope in one direction only; otherwise, special precautions must be taken to prevent soil washing. Each plat should be graded and slightly crowned in the middle to avoid depressions where water might stand or ice might form. This can be accomplished by plowing each plat by itself with the back furrow in the middle of the plat. Land subject to erosion must be only very slightly crowned. This grading or crowning of the plats should be done before any special soil treatments are applied.

Drainage.—When artificial drainage is required, the drains should be located as so to influence all plats alike. Where irrigation is practiced provision must be made to water all plats at the same time and at the same rate.

Size of Plats.—While the size of plats must often be governed by the number of plats required for the particular experiment and the amount of land available, twentieth-acre to tenth-acre plats will usually be found most desirable where horse and machine labor are to be used. There is seldom any advantage in larger plats. No field of any considerable area is altogether uniform. Where a large number of plats is required for the experiment, the smaller size will usually be most desirable because of unavoidable soil variations between the first and last plats of a large series and the time required for cultural operations.

Shape of Plats.—Long and narrow plats laid out crosswise of the greatest soil variation are preferable to square or short and broad plats because the latter are more likely to show important differences in natural productivity. The long, narrow plats are also most convenient in conducting cultural operations. For example, a plat 14 feet in width can be seeded by one round of a 7-foot grain drill and will accomodate four corn rows, and generally something near this

width should be regarded as a minimum. Extremely narrow plats increase the difficulty of keeping fertilizer or manure treatments within the plat limits.

Marking the Plats.—The four corners of any series of plats should be marked by permanent markers set below the bottom of the plow furrow as a basis from which to measure in case individual plat stakes should be moved out of line. Markers for individual plat boundaries should be set in the turnways even with the surface of the ground so that implements will pass over them.

Frequency of Check-Plats.—Uniformly treated plats through which to compare the different treatments in the experiment should be regularly distributed throughout the series. At least every fourth plat should be such a check. Having every third plat a check is preferable since this provides a check plat on one side or the other of each differently treated plat in the experiment.

Treatment of Check Plats.—All check plats should receive a uniform soil treatment that will maintain them in a reasonable state of productiveness and make possible a normal growth of each crop in the rotation. This will provide a uniform standard of comparison throughout the duration of the experiment.

Untreated Plats.—One or more plats receiving no soil treatment whatever should be included in each series of plats employed in the experiment to show how the soil naturally behaves under the particular system of cropping to which it is subjected. In large series, there should be one such untreated plat at each end and one in the middle.

Replication of Treatments.—The complete series of treatments, including check plats, should be repeated as many times as there are crops in the rotation employed. Thus, with a 4-year rotation there should be four series of plats in each of which the entire set of treatments is repeated in the same order. This provides for growing every crop in the rotation every year, subjects every crop to the same seasonal influences, and gives four differently located plats to get a fair average of the effect of each treatment on the particular soil type for each crop as well as for the rotation as a whole. When the experiment deals with a single crop, the entire series of plats should be at least duplicated on the same soil type. In general soil fertility tests, at least three crops of different classes should be used, as, for example, a cultivated crop, such as corn, a small grain crop, and a clover or grass crop.

Interspaces and Borders.—The plats in all soil productivity series should be separated by untreated interspaces at least three feet in

width. Where corn or other cultivated crops are included in the rotation, the interspace may conveniently consist of one row planted in the middle of the space and removed at harvest time. For small grains and hay crops the interspace may be either sown the same as the plats and cut out at harvest time or it may be left unsowed and kept clean by cultivation. There should also be interspaces between the outside plats and borders.

The entire series of plats should be surrounded by regularly planted side and end border strips to be cut off at harvest time. Such borders should be at least 3 feet wide or equal to one or two hills or rows where cultivated crops are included in the rotation. Borders and division strips set with permanent grass may be substituted for cultivated borders and division strips, and may be advisable where there is danger of soil washing from one plat to the next.

Uniform Stand of Plants.—Only tested, high quality, acclimated seed should be planted. Wherever possible seed of a pure line or of an especially pure sort should be used. The seed bed must be uniformly prepared and the rate and method of seeding should be such as to secure a uniform, normal stand of plants on all plats. Hill-planted crops should be planted thicker than required and then thinned to the desired stand soon after the plants are up. It is often wise to plant extra hills for transplanting to fill up gaps in the stand.

Use of Check Plats in Making Comparisons Between Differently Treated Plats.—When frequent, uniformly treated and equally distributed, check plats are employed it is usually most satisfactory to assume that the difference between any two check plats is uniformly progressive and calculate a normal check yield for each intervening plat as a basis for determining the effect of the particular treatment. While this method is seldom, if ever, strictly accurate, it is usually better than to compare directly with the nearest check plat or with either the average of the two nearest checks or the average of all the check plats in the series. It is therefore recommended that calculations of increases produced by treatments be based on the assumption that the difference between the two nearest check plats is uniformly progressive. Thus, if plats 1 and 4 are uniformly treated check plats and plat 1 has produced 50 bushels of corn and plat 4 has produced 53 bushels, it should be assumed that plat 2 would have produced 51 bushels and plat 3 would have produced 52 bushels, if they had received the same treatment as plats 1 and 4. Then, if plat 2 actually produced 56 bushels, the increase credited to the treatment would be 5 bushels and if plat 3 actually produced 58 bushels the increase credited to the treatment would be 6 bushels.

Cultural Operations.—All cultural operations except plowing should be conducted lengthwise of the plats to avoid all possibility of moving soil or fertilizer materials from one plat to another, except perhaps that hill planted crops may be cross cultivated once or twice to clear out weeds, using implements that will not drag the soil. Plowing should usually be crosswise of the plats with a double or right- and left-hand plow, beginning at one end of the plats and turning all the furrows one way and leaving no dead-furrow. Where grass division strips are used, the plowing should be lengthwise and all plats should be plowed on the same day. The direction of turning the furrow should be alternated at successive plowings. Any one cultural operation should be performed with only one implement without change of adjustment and should be completed on the same day. Interruptions in cultural operations may cause serious differences in crop development. For this reason, in large series, two or three implements of the same make, and similarly adjusted will hasten the work and avoid delays which may otherwise be caused by weather conditions.

Determining Yields.—Yields should usually be determined by harvesting and weighing the produce of the entire plat. The produce must be uniformly dried before weighing. In case this can not be done, the moisture content should be determined and proper corrections made before recording the weights.

RECOMMENDED STANDARDS FOR FIELD EXPERIMENTS WITH FARM CROPS

The Seed.—All seeds used for planting shall be of known vitality and free from mixture, weed seeds, and contamination or infection by plant diseases, so far as this can reasonably be accomplished. All seeds for any particular experiment should be kept under the same storage conditions. So far as possible seeds should be graded to a standard size as an aid to securing uniform stands of plants.

Except where adaptation of varieties or effects of previous environment is an essential part of an experiment acclimated seed only shall be used. In varietal tests of corn, where crossing make a strict observance of this rule impractical, it is recommended that seed be used that has been grown as near as possible to the locality where the test is to be conducted.

Careful efforts to identify unknown varieties introduced into experimental work should be made before publication of results and new names should not be applied except in case of necessity. New vari-

eties should be named as soon as it is decided to release them for general use. Records of the history of all seeds used should be made and kept on file.

The Soil.—The soil for experimental plats should be as nearly as possible of the type prevailing in the area where the data from the crops grown on them are to be applied.

Where artificial drainage is required, the drains should be located so as to influence all the plats alike. Where irrigation is practiced the applications of water must be regulated and made the same for all plats.

The lay of the land and the general condition of the soil should be as uniform as possible. Slopes steep enough to wash materially must be avoided. It is important that for several years prior to its use for experimental purposes, the cropping, fertilization, and tillage of the land shall have been uniform.

Good rotation accompanied by ordinary fertilization are necessary in varietal and cultural work to keep the productivity of the soil up to normal.

When a field, or series of plats, has been occupied by varietal or cultural tests, at least one bulk crop should intervene before it is again used for such tests.

The Plats.—As a rule, relatively long and narrow plats are to be preferred, both because of convenience in using machinery and because of greater accuracy on uneven land, in which case the plats should be laid out so that all will partake alike in the inequalities of the soil. The width of plats should be sufficient to allow for the removal of border rows, as hereinafter provided for, and to permit the most convenient use of machinery. Plats 5 feet or more in width, for small grains and forage crops, and wide enough for four rows of intertilled crops, such as corn and potatoes, are generally satisfactory. The length of plats may be determined largely by the amount and character of the land available. In general, field plats should not be smaller than one-eightieth nor larger than one-twentieth of an acre.

Wherever possible all the plats of an experiment should be located on the same piece of land. When, for lack of sufficient space, it becomes necessary to locate part of the plats in any particular experiment on a different piece of land, the break should always be made where a replication of varieties or treatments begins.

For rotation work and for ascertaining the effect of crops on those which follow, it is necessary to establish permanently the boundaries of each plat by setting suitable markers. For these purposes, plats should be at least 1 rod wide.

Check plats.—Adequate replication of varieties or treatments removes the necessity of including check plats. If check plats are included for the purpose of deriving probable errors from yields, a large proportion of such plats appears to be necessary. If a check variety is used in varietal tests, it should be used on every third to every fifth plat and it should be a standard, well adapted variety.

Replication of Plats.—The number of years a test is continued, together with the number of plats devoted to any one variety or treatment and the size of the plats, relate definitely to the probable error for any particular test. When single plats of varieties or treatments are used, the probable error will average lower on tenth-acre plats than on plats of smaller size. The increase in probable error on successively smaller plats is relatively small when the decided reduction in size of plats is considered. By repeating varieties or treatments a sufficient number of times on regularly distributed plats of any size suitable to the purpose of the experiment, the probable error for the test may be considerably reduced. For ordinary conditions, from two to five replications are recommended. Two plats of any variety or treatment continued through four years, or three plats continued through three years should be regarded as the minimum.

Removing Outside Rows.—When varieties are planted adjacent to each other, without the intervention of alleys, certain ones may affect others adversely. When plats are flanked or surrounded by alleys, it is known that the yields are increased and that all varieties are not influenced alike. To obviate these difficulties, it is recommended that two drill rows from either side of each plat in the case of small grain, and an equivalent width in the case of broadcasted grains or forage crops, and one row from either side of each plat in intertilled crops, be either removed before harvest or left unharvested.

The Mechanical Operations.—Drills and planters should be carefully calibrated before seeding. A check on the stand should be secured by counting plants before tillering takes place. In the case of the larger intertilled crops, the seeding should be somewhat thicker than necessary and the stand thinned to the desired degree at an early stage of growth. In varietal tests where different varieties have different sized seeds, the rate of seeding drilled or broadcasted crops should be adjusted so as to get as nearly as possible the same stand of plants for all the varieties in the test. With hill planted crops such as corn, in which large and small varieties are included in the same test, there may need to be two or three different rates of planting of certain varieties so as to insure fair comparisons.

All operations should be uniform for any one experiment. Plowing,

seeding, or any one cultural operation should be begun and finished on the same day.

Determining Yields.—When it is impractical to harvest and determine yields from entire plats, a minimum of six representative rod-rows or square yards, or other areas of similar size, uniformly distributed within the plat, avoiding borders, may be used.

Two capable men should be present at all times when weighings are made, with definite instructions that all weights must be checked.

In determining yields, possible differences in the moisture content of the crop should be considered and moisture determinations and proper corrections made when necessary. This is of special importance in tests with forage crops and in the case of late maturing varieties of corn.

The results of varietal tests on rich land should not be averaged with those on poor land, but should be used separately with the view of determining the adaptability of the varieties to each condition.

The Publication and Interpretation of Results.—It is recommended that sufficient data be published to permit the reader to draw independent conclusions.

For technical and semi-technical publications it is recommended that, so far as practicable, probable errors with the author's accepted odds or the probability, be given, together with such data as will enable the reader to determine how they were derived. In experiments where probable error calculations are not feasible, it is nevertheless important to keep the probable error concept in mind when interpreting the results or drawing conclusions. Even in popular articles, regard should be given to the probable error concept.

New varieties, cultural methods, or treatments materially different from those in common usage should not be recommended for general use unless supported by at least three years of replicated and carefully conducted field experiments within the area for which the recommendations are made. This shall not be interpreted as sanctioning such recommendations simply because they are supported by the minimum of experimental data nor as discouraging the early publications of experimental results for the benefit of technical workers.

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BIBLIOGRAPHY OF STANDARDIZATION OF FIELD EXPERIMENTS

1. ALEXANDROWITSCH, I. Determinations of probable errors in field experiments. *In* Mitt. Deut. Landw. Gesell., 28:268–271. 1913.

2. ALLISON, F. E., and COLEMAN, D. A. Biological variations in soil plots as shown by different methods of sampling. *In* Soil Science, 3:499–514. 1917.

3. ALWAY, F. J., and FILES, E. K. On the sampling of cultivated soils. *In* 25th Ann. Rept. Nebr. Agr. Expt. Sta., p. 52–55. 1912.

4. ALWAY, F. J., and TRUMBULL, R. S. On the sampling of prairie soils. *In* 25th Ann. Rept. Nebr. Agr. Expt. Sta., p. 35–51. 1912.

5. ALWOOD, W. B., and PRICE, R. H. Suggestions regarding size of plats. Va. Agr. Expt. Sta. Bul. 6. 1890.

6. ANTHONY, R. D., and WARING, J. H. Methods of interpreting yield records in apple fertilization experiments. Penn. Agr. Expt. Sta. Bul. 173. 1922.

7. ARNY, A. C., and GARBER, R. J. Field technic in determining yields of plots of grain by the rod-row method. *In* Jour. Amer. Soc. Agron., 11:33–47. 1919.

8. ARNY, A. C., and HAYES, H. K. Experiments in field technic in plot tests. *In* Jour. Agr. Res. 15:251–262. 1918.

9. ARNEY, A. C., and STEINMETZ, F. H. Field technic in determining yields of experimental plots by the square-yard method. *In* Jour. Amer. Soc. Agron., 11:81–106. 1919.

10. ARNY, A. C. Further experiments in field technic in plot tests. *In* Jour. Agr. Res., 21:483–499. 1921.

11. ARNY, A. C. Border effect and ways of avoiding it. *In* Jour. Amer. Soc. Agron., 14:266–278. 1922.

12. ATWATER, W. O. Cooperative experimenting as a means of studying the effects of fertilizers and the feeding capacities of plants. U. S. Dept. Agr., Special Rpt. 18. 1882.

13. ATWATER, W. O. Results of field experiments with various fertilizers. U. S. Dept. Agr., Special Bul. 31. 1883.

14. BABCOCK, F. R. Cereal experiments at the Williston, N. Dak., substation. U. S. Dept. Agr. Bul. 270. 1915.

15. BARBER, CLARENCE W. Note on the Influence of shape and size of plots in tests of varieties of grain. Maine Agr. Expt. Sta. Bul. 226, p. 76–84. 1914.

16. BATCHELOR, L. D., and REED, H. S. Relation of the variability of yields of fruit trees to the accuracy of field trials. *In* Jour. Agr. Res., 12:245–283. 1918.

17. BATYRENKO, V. G. The experimental error in field tests. *In* Zhur. Opuitn. Agron. (Russ. Jour. Expt. Landw.), 17:99–121. 1916. Abs. in Expt. Sta. Rec., 37:528. 1917.

18. BAULE, B. Über die Verwertung der Fehlertheorie in der Land und Forstwirtschaft. *In* Fühling's Landw. Ztg., 62:852–866. 1913.

19. BEAR, F. E., and MCCLURE, G. M. Sampling soil plats. *In* Soil Science, 9:65–75. 1920.

20. BILGER, O. A method for variety tests. *In* Illus. Landw. Ztg., 32:827–829. 1912.

21. BOLLEY, H. L. Interpretation of results noted in experiments upon cereal cropping methods after soil sterilization. *In* Proc. Amer. Soc. Agron., 2 (1910):81–85. 1911.

22. BONNETT, R. K., and BURKART, F. L. Rate of seeding—a factor in variety tests. *In* Jour. Amer. Soc. Agron., 15:161–171. 1923.

23. BROWN, B. A. Plot competition in potatoes. *In* Jour. Amer. Soc. Agron., 14:257–258. 1922.

24. BROWN, P. E. Soil types as a basis for soil investigations. *In* Jour. Amer. Soc. Agron., 14:193–206. 1922.

25. BUCKMAN, H. O. Fertilizing the rotation. *In* Jour. Amer. Soc. Agron., 5:157–164. 1913.

26. BULL, C. P. The row method and the centgener method of breeding small grains. *In* Proc. Amer. Soc. Agron., 1 (1907–09):95–97. 1910.

27. CARDON, P. V. Tillage and rotation experiments at Nephi, Utah. U. S. Dept. Agr. Bul. 157. 1915.

28. CARLETON, M. A. Limitation in field experiments. *In* Proc. Soc. Prom. Agr. Science, 30:55–61. 1909.

29. CARRIER, LYMAN. A reason for the contradictory results in corn experiments. *In* Jour. Amer. Soc. Agron., 11:106–113. 1919.

30. CHAMPLIN, MANLEY. The technique of field husbandry experimentation. *In* Scientific Agriculture, 2:14–18. 1921.

31. CHRISTENSEN, H. R. Experiments in methods for determining the reaction of soils. *In* Soil Science, 4:115–178. 1917.

32. COFFEY, G. N. The purpose and interpretation of field experiments. *In* Jour. Amer. Soc. Agron., 5:222–230. 1913.

33. COFFEY, G. N., and TUTTLE, H. FOLEY. Pot tests with fertilizers compared with field trials. *In* Jour. Amer. Soc. Agron., 7:129–139. 1915.

34. COLLINS, G. N. A more accurate method of comparing first generation maize hybrids with their parents. *In* Jour. Agr. Res., 3:85–91. 1914.

35. COOMBS, G. E., and GRANTHAM, J. Field experiments and the interpretation of their results. *In* Fed. Malay States Agr. Bul., 4:206. 1909.

36. CORY, V. L. The use of row plantings to check field plats. *In* Proc. Amer. Soc. Agron., 1 (1907–09):68–70. 1910.

37. DAFERT, F. W. Einige Bemerkungen über den Zweck und die Durchführung von Felddüngungsversuchen. *In* Landw. Jahrb., 32:149–159. 1903.

38. DAVENPORT, E. Principles of Breeding, 721 p. Ginn & Co., Boston. 1907.

39. DAVENPORT, E., and FRAZER, W. J. Experiments with wheat, 1888–1895. Ill. Agr. Expt. Sta. Bul. 41, p. 153–155. 1896.

40. DAY, J. W. The relation of size, shape and number of replications of plots to probable error in field experiments. *In* Jour. Amer. Soc. Agron., 12:100–105. 1920.

41. DENNY, F. E. Formula for calculating the number of fruits required for an adequate sample for analysis. *In* Bot. Gaz., 73:1–445.

42. DEVRIES, O. On the effect of using many parallel plats in field experiments. *In* Teysmannia, 26:465–474. 1915.

43. DRECHSLER, G. Düngungsversuche auf dem Versuchsfelde des landw. Instituts der Universität Göttingen. *In* Jour. Landw., 28:243–271. 1880.

44. DRECHSLER, G. Die Theorie der Düngung und die Aufgabe der Düngungsversuche. *In* Jour. Landw., 32:308–336. 1884.
45. EDLER, W. Versuche zur Ermittelung des Düngerbedurfnisses des Ackerbodens. *In* Jour. Landw., 46:349–365. 1898.
46. EHRENBURG, P. Versuch eines Beweises für die Anwendbarkeit der Wahrscheinlichkeitsrechnung bei Feldversuchen. *In* Landw. Vers. Stat., 87:29–88. 1915.
47. EHRENBURG, P. The nitrogen economy of cultivated soils. *In* Fühlings Landw. Ztg., 581:241–246. 1909.
48. EVANS, M. W. Some methods of recording data in timothy breeding. *In* Jour. Amer. Soc. Agron., 14:62–69. 1922.
49. FARRELL, F. D. Interpreting the variation of plat yields. *In* U. S. Dept. Agr., Bur. Plant Ind. Circ. 109:27–32. 1913.
50. FARRELL, F. D. Basing alfalfa yields on green weights. *In* Jour. Amer. Soc. Agron., 6:42–45. 1914.
51. FAULKNER, O. T. Unavoidable error of field experiments. *In* Agr. J. of India 18:238–248. 1923.
52. FISHER ARNE. The Mathematical Theory of Probabilities and its Application to Frequency Curves and Statistical Methods. The Macmillan Co., New York. 1916.
53. GARDNER, F. D., and RUNK, J. A. Variety test of oats. *In* Ann. Rpt. Pa. State College (1910–1911):164. 1912.
54. GILES, P. L. On the plans of fertilizer experiments. *In* Jour. Amer. Soc. Agron., 6:36–41. 1914.
55. GRANTHAM, A. E. The effect of rate of seeding on competition in wheat varieties. *In* Jour. Amer. Soc. Agron., 6:124–128. 1914.
56. GREGOIRE, A. Field experiments and the interpretation of their results. *In* Rpt. Tenth Cong. Internat. Agr. Grand., sec. 2, question 1, 13 p. 1913.
57. HALL, A. D. Fertilizers and Manures, 367 p. E. P. Dutton & Co., New York, 1909.
58. HALL, A. D. The experimental error in field trials. *In* Jour. Bd. Agr. (London), 16:2 365–370. 1909.
59. HALL, A. D., and RUSSELL, E. J. Field trials and their interpretation. *In* Jour. Bd. Agr. (London), Supplement, p. 5–14. Nov., 1911.
60. HANROTH, ——. Determination of probable error in field experiments. *In* Mitt. Deutsch. Landw. Gesell., 28:70–73, 87–90, 105–107. 1913.
61. HARRIS, J. A. On the significance of variety tests. *In* Science, n. s., 36:318–320. 1912.
62. HARRIS, J. A. Supplementary note on the significance of variety tests. *In* Science, n. s., 37:493, 494. 1913.
63. HARRIS, J. A. An illustration of the influence of substratum heterogeneity upon experimental results. *In* Science, n. s., 38:345–346. 1913.
64. HARRIS, J. A. On a criterion of substratum homogeneity (or heterogeneity) in field experiments. *In* Amer. Nat., 49:430–454. 1915.
65. HARRIS, J. A. Practical universality of field heterogeneity as a factor influencing plat yields. *In* Jour. Agr. Res., 19:279–315. 1920.
66. HARRIS, J. A., and SCOFIELD, C. S. Permanence of differences in the plats of an experimental field. *In* Jour. Agr. Res., 20:335–356. 1920.
67. HARRIS, F. S., and BUTT, N. I. The unreliability of shorttime experiments. *In* Jour. Amer. Soc. Agron., 12:158–167. 1920.

68. HARTLEY, C. P., BROWN, E. B., KYLE, C. H., and ZOOK, L. L. Cross-breeding corn. U. S. Dept. Agr., Bur. Plant Ind. Bul. 218, 66 pp. 1912.
69. HAYES, H. K., and ARNY, A. C. Experiments in field technic in rod row tests. *In* Jour. Agr. Res., 11:399–419. 1917.
70. HAYES, H. K. Controlling experimental error in nursery trials. *In* Jour. Amer. Soc. Agron., 15:177–192. 1923.
71. HEDRICK, U. P. A comparison of tillage and sod mulch in an apple orchard. N. Y. State (Geneva) Agr. Expt. Sta. Bul. 314. 1909.
72. HEDRICK, U. P. Is it necessary to fertilize an apple orchard? N. Y. State (Geneva) Agr. Expt. Sta. Bul. 339. 1911.
73. HILGARD, E. W. Soil tests and variety tests. *In* Proc. Soc. Prom. Agr. Sci., p. 89–94. 1901.
74. HILL, C. E. A drill for seeding nursery rows. *In* Jour. Amer. Soc. Agron., 10:165–166. 1918.
75. HOLTSMARK, G., and LARSEN, B. R. Über die Fehler, welche bei Feldversuchen durch die Ungleichartigkeit des Bodens bedingt werden. *In* Landw. Vers. Sta., 65:1–22. 1906.
76. HUNNICUTT, B. H. Some Brazilian problems in agronomy. *In* Jour. Amer. Soc. Agron., 5:34–38. 1913.
77. HUSTON, H. A. Field tests with fertilizers. *In* Original Communications 8th Internat. Congress Appl. Chem., 15:139. 1912.
78. JACK, H. W. Observations on the technique required in field experiments with rice. Fed. Malay States Dept. Agr. Bul. 32. 1921.
79. JARDINE, W. M. Methods of studying the relative yielding power of kernels of different sizes. *In* Proc. Amer. Soc. Agron., 1 (1907–09):104–108. 1910.
80. KASERER, H. Beitrag zur Frage der Feststellung des Nährstoffegehaltes einer Ackerparzelle. *In* Ztschr. Landw. Versuchsw. Osterr., 13:742–747. 1910.
81. KEMP, W. B. An index for measuring the performance of wheat varieties and strains. *In* Jour. Amer. Soc. Agron., 14:258–265. 1922.
82. KIESSELBACH, T. A. Studies concerning the elimination of experimental error in comparative crop tests. Nebr. Agr. Expt. Sta. Res. Bul. 13, 91 p. 1918.
83. KIESSELBACH, T. A. Experimental error in field trials. *In* Jour. Amer. Soc. Agron., 11:235–241. 1919.
84. KIESSELBACH, T. A. Plat competition as a source of error in crop tests. *In* Jour. Amer. Soc. Agron., 11:242–247. 1919.
85. KIESSELBACH, T. A. Competition as a source of error in comparative corn yields. *In* Jour. Amer. Soc. Agron., 15:199–215. 1923.
86. KLINCK, L. S. The improvement of small grains at Macdonald college. *In* Proc. Amer. Soc. Agron., 4:126–129. 1912.
87. KOENIG, M. Experimental error of field trials under Mauritius conditions. Mauritius Dept. of Agri., Sci. Ser. Bul. 7 (1922). English ed.
88. KOSTECKI, E. Methods of testing varieties. *In* Trudy Biuro Prikl. Bot. (Bul. Agnew. Bot.), 5:177–204. 1912.
89. LEHN, D. New work on methods for variety testing. *In* Bl. Zuckerrübenbau, 20:33–39 and 52–55. 1913.
90. LEIDNER, R. Field experiments and compensating calculations. *In* Landw. Jahrb., 49:105–135. 1916. Abs. in Expt. Sta. Rec., 37:528. 1917.

91. LEIDNER, R. Proposals for simplifying the technic of field experiments. *In* Bab. Abstracts, 12:1–7. Abs. in Landw. Jahrb., 54–283. 1919.

92. LEIDNER, R. Field experiments and compensating calculations. Landw. Jahrb., 49 (1916) 1–105. Abs. in Expt. Sta. Rec., 37–572. 1917.

93. LIEBSCHER, G. Untersuchengen über die Bestimmung Düngerbedurfnisses der Ackerboden und Kulturpflanzen. *In* Jour. Landw., 43:49–80. 1895.

94. LOVE, H. H., and CRAIG, W. T. Methods and results obtained in cereal investigations at the Cornell station. *In* Jour. Amer. Soc. Agron., 10:145–157. 1918.

95. LOVE, H. H. The experimental error in field trials. *In* Jour. Amer. Soc. Agron., 11:212–216. 1919.

96. LOVE, H. H. The application of probable error to agricultural experimentation. *In* Proceedings of the 36th Annual Convention of the Association of Land-Grant Colleges, pp. 129–140. 1922.

97. LOVE, H. H. The importance of the probable error concept in the interpretation of experimental results. *In* Jour. Amer. Soc. Agron., 15:217–224. 1923.

98. LYON, T. L. A test of planting plats with the same ears of corn to secure greater uniformity in yield. *In* Proc. Amer. Soc. Agron., 2 (1910):35–37. 1911.

99. LYON, T. L. A comparison of the error in yield of wheat from plats and from single rows in multiple series. *In* Proc. Amer. Soc. Agron., 2 (1910): 38, 39. 1911.

100. LYON, T. L. Some experiments to estimate errors in field plat tests. *In* Proc. Amer. Soc. Agron., 3 (1911):89–114. 1912.

101. MALTE, M. O. 1000 kernel weight of seed in relation to experimental error. *In* Scientific Agriculture, 3:69–71. 1922.

102. MAYER, A. E. Beiträge zur Frage über die Düngung mit Kalisalzen. *In* Landw. Vers. Stat., 26:309–351. 1881.

103. MCKEE, R. Moisture as a factor of error in determining forage yields. *In* Jour. Amer. Soc. Agron., 6:113–117. 1914.

104. MCCALL, A. G. A new method for harvesting small grain and grass plots. *In* Jour. Amer. Soc. Agron., 9:138–141. 1917.

105. MERCER, W. B., and HALL, A. D. The experimental error in field trials. *In* Jour. Agr. Science, 4:107–132. 1911.

106. MITSCHERLICH, E. A. Landwirtschaftliche Vegetationsversuche. *In* Landw. Jahrb., 32:773–818. 1903.

107. MITSCHERLICH, E. A. Über landwirtschaftliche Vegetationsversuche und die Verarbeitung der Resultate derselben. *In* Landw. Vers. Stat., 61:285–303. 1904.

108. MITSCHERLICH, E. A. Zur Methodik der Felddüngungs und der Sortenanbau-Versuche. *In* Landw. Jahrb., 424:15–421. 1912.

109. MITSCHERLICH, E. A., and DUHRING, FRANZ. Über die Grösze der Teilstücke bei Feldversuchen. *In* Landw. Vers. Stat. 98:365–383. 1921.

110. MIYAKE, C. The experimental error in field trials and the effect on this error of various methods of sampling. *In* Ber. Ohara Inst. Landw. Forsch., 1:111–121. 1916.

111. MONTGOMERY, E. G. Methods of testing the seed value of light and heavy kernels in cereals. *In* Proc. Amer. Soc. Agron., 2 (1910):59–69. 1911.

112. MONTGOMERY, E. G. Variation in yield and methods of arranging plats to secure comparative results. *In* 25th Ann. Rpt. Nebr. Agr. Expt. Sta., p. 164–180. 1911.
113. MONTGOMERY, E. G. Experiments in wheat breeding. U. S. Dept. Agr., Bur. Plant Ind. Bul. 269. 1913.
114. MOOERS, C. A. The agronomic placement of varieties. *In* Jour. Amer. Soc. Agron., 13:337–352. 1921.
115. MOORE, R. A. The testing of varieties as foundation work in the improvement of farm crops. *In* Proc. Amer. Soc. Agron., 1 (1907–09):27–28. 1910.
116. MORGAN, J. O. Some experiments to determine the uniformity of certain plats for field tests. *In* Proc. Amer. Soc. Agron., 1 (1907–09): 58–67. 1910.
117. MORTENSEN, M. L. The technique of field experiments. *In* Jahresber. Ver. Angew, Bot., 9:177–187. 1911. Abs. in Expt. Sta. Rec., 29:734, 735. 1913.
118. MYERS, C. H., and PERRY, F. R. Analysis and interpretation of data obtained in comparative tests of potatoes. *In* Jour. Amer. Soc. Agron. 15:239–253. 1923.
119. NORGORD, C. P. Crop demonstrations on state and county farms. Wis. Agr. Expt. Sta. Bul. 208. 1911.
120. OLMSTEAD, L. B. Some applications of the methods of least squares to agricultural experiments. *In* Jour. Amer. Soc. Agron., 61–90–204. 1914.
121. PARISH, E. Agricultural experiment: Its design and interpretation. Union So. Africa Dept. Agr. Sci. Bul. 22. 1922.
122. PEARL, E., and MINER, J. R. A table for estimating the significance of statistical constants. Maine Agr. Expt. Sta. Bul. 226, p. 85–88. 1914.
123. PFEIFFER, T., and BLANCK, E. Die Bedeutung des Analysenfehlers bei der Entscheidung von Fragen über den Stickstoffhaushalt des Ackerbodens. *In* Landw. Vers. Stat., 78–367–374. 1912.
124. PICKERING, S. M. Experimental error in horticultural work. In Jour. Bd. Agr. (London) Supplement, p. 38–47. Nov., 1911.
125. PIPER, C. V., and STEVENSON, W. H. Standardization of field experimental methods in agronomy. *In* Proc. Amer. Soc. Agron., 2 (1910): 70–76. 1911.
126. PRITCHARD, F. J. The use of checks and repeated plantings in varietal tests. *In* Jour. Amer. Soc. Agron., 8:65–81. 1916.
127. ROBINSON, G. W., and LLOYD, W. E. On the probable error of sampling in soil surveys. *In* Jour. Agr. Sci., 7:144–153. 1915.
128. ROEMER, THEODOR. Der Feldversuch. *In* Arb. der Deut. Landw. Gesel. 302:34–35. 1920.
129. ROEMER, T. Theory of probabilities applied to field experiments. *In* Int. R. Sci. & Prac. Agr. 12:250–253. 1921.
130. ROGALSKI, B. To what extent can the results of fertilizer and variety tests be influenced and thus lead to false conclusions? *In* Illus. Landw. Ztg., 34:400–401 and 407–408. 1914.
131. ROSE, R. E. Methods of conducting fertilizer tests. *In* Amer. Fert., 35:21–23. 1911.
132. SALMON, C. A practical method of reducing experimental error in varietal tests. *In* Jour. Amer. Soc. Agron., 5:182–184. 1913.

THN, C. Check plats as a source of error in varietal tests. *In* Jour. Amer. Soc. Agron., 6:128–131. 1914.

134. SALMON, C. Cereal investigations on the Belle Fourche Experiment Farm. U. S. Dept. Agr. Bul. 297. 1915.

135. SALMON, S. C. Some limitations in the application of the method of least squares to field experiments. *In* Jour. Amer. Soc. Agron., 15:225–239. 1923.

136. SCHNEIDEWIND, W. Experiments with different sized plats. *In* Mitt. Deut. Landw. Gesell., 39:298–300. 1914.

137. SCHNEIDEWIND, W., MEYER, D., and MUNTER, F. Parcel size experiments. *In* Arb. Deut. Landw. Gesell., 296:51. 1919. Abs. in Expt. Sta. Rec., 44:214. 1920.

138. SCHOLZ, H. Methods of conducting variety trials. *In* Fühlings Landw. Ztg., 23:807–830. 1910. 59:776–785.

139. SCHREINER, OSWALD, and SKINNER, J. J. The triangle system of fertilizer experiments. *In* Jour. Amer. Soc. Agron., 10:225–246. 1918.

140. SEBELIEN, J. Modern methods for experiments with fertilizers and manures. *In* Jour. Agr. Sci., 10:415–419. 1920.

141. SMITH, L. H. Plot arrangement for variety experiments with corn. *In* Proc. Amer. Soc. Agron., 1 (1907–09):84–89. 1910.

142. SPILLMAN, W. J. The basis for estimating the yield of hay. *In* Proc. Amer. Soc. Agron., 1 (1907–09):158, 159. 1910.

143. SPILLMAN, W. J. Study of farm practice vs. field experiments. *In* Proc. Soc. Prom. Agr. Science, 33:103–113. 1912.

144. SPILLMAN, W. J. A plan for the conduct of fertilizer experiments. *In* Jour. Amer. Soc. Agron., 13 304–310. 1921.

145. SPRAGG, FRANK A. Methods of keeping crop records at the Michigan Experiment Station. *In* Proc. Amer. Soc. Agron., 2 (1910):43–54. 1911.

146. SPRAGG, F. A. Elimination of error. *In* 28th Ann. Rpt. Mich. Agr. Expt. Sta., p. 226–228. 1915.

147. STADLER, L. J. Experiments in field plot technic for the preliminary determination of comparative yields in small grains. Mo. Agr. Expt. Sta. Res. Bul. 49. 1921.

148. STEWART, F. C. Missing hills in potato fields: their effect upon yield. N. Y. State (Geneva) Agr. Expt. Sta. Bul. 459. p. 45–69. 1919.

149. STEWART, F. C. Further studies in the effect of missing hills in potato fields and on the variation in the yield of potato plants from halves, of the same seed tuber. N. Y. State (Geneva) Agr. Expt. Sta. Bul. 489. 1921.

150. STEWART, JOHN P. The fertilization of apple orchards. *In* Pa. Agr. Exp. Sta. Ann. Rpt. 1909–1910:279–300. 1910.

151. STOCKBERGER, W. W. Relative precision of formulae for calculating normal plot yields. *In* Jour. Amer. Soc. Agron., 8:167–175. 1916.

152. STUDENT, ——. The probable error of a mean. Biometrika. Vol. 6:1–25. 1908.

153. SUMMERBY, R. Replication in relation to accuracy in comparative field tests. *In* Jour. Amer. Soc. Agron., 15:192–199. 1923.

154. SURFACE, FRANK M., and PEARL, RAYMOND. A method for correcting for soil heterogeneity in variety tests. *In* Jour. Agr. Research, 5:1039–1049. 1916.

155. TAYLOR, F. W. The size of experiment plots for field crops. *In* Pts Amer. Soc. Agron., 1 (1907–09):56–58. 1910.

156. TEN EYCK, A. M. The testing of varieties as foundation work in the improvement of farm crops. *In* Proc. Amer. Soc. Agron. 1 (1907–09): 33–39. 1910.

157. THORNE, C. E. Essentials of successful field experimentation. Ohio Agr. Expt. Sta. Circ. 96. 1909.

158. THORNE, C. E. The interpretation of field experiments. *In* Proc. Amer. Soc. Agron., 1 (1907–09):45–55. 1910.

159. THORNE, C. E. Interpreting fertilizer tests. *In* Jour. Amer. Soc. Agron., 5:129–137. 1913.

160. TUCKER, G. M. Uniformity in experimental agronomic work. *In* Jour. Amer. Soc. Agron., 6:131, 132. 1914.

161. VINALL, H. N., and MCKEE, R. Moisture content and shrinkage of forage and relation of factors to the accuracy of experimental data. U. S. Dept. Agr. Bul. 353. 1916.

162. VON RUMKER, K., LEIDNER, K. R., and ALEXANDROWITSCH, I. The application of a new method in variety tests of cereals. *In* Ztschr. Pflanzenzücht, 2:189–232. 1914.

163. WAGNER, P. Beiträge zur Begründung und Ausbildung einer exakten der Methode der Düngungsversuche. *In* Jour. Landw., 28:9–57. 1881.

164. WAGNER, P. Einige Resultate agriculturchemischer Düngungsversuche. *In* Jour. Landw., 31:225–275. 1883.

165. WAGNER, P. Die Stickstoffdüngen der landwirtschaftlichen Kulturpflanzen. Berlin, P. Parey, 1892.

166. WALLER, A. E., and THATCHER, L. E. Improved technic in preventing access of stray pollen. *In* Jour. Amer. Soc. Agron., 9:191–195. 1917.

167. WARREN, G. F. Some business questions involved in the interpretation of fertilizer tests. *In* Proc. Amer. Soc. Agron., 4:62–66. 1912.

168. WARREN, G. F. Further notes on interpreting fertilizer tests. *In* Jour. Amer. Soc. Agron., 137–140. 1913.

169. WENHOLZ, H. A new method for determining yields of experimental plots. *In* Agr. Gaz. New So. Wales, 32:499. 1921.

170. WHEELER, H. J. Some desirable precautions in plat experimentation. *In* Proc. Amer. Soc. Agron., 1 (1907–09):39–44. 1910.

171. WIANCKO, A. T. The testing of varieties as foundation work in the improvement of farm crops. *In* Proc. Amer. Soc. Agron., 1 (1907–09):29–33. 1910.

172. WIANCKO, A. T. Use and Management of check plats in soil fertility investigations. *In* Jour. Amer. Soc. Agron., 6:122–124. 1914.

173. WOOD, T. B. The interpretation of experimental results. *In* Jour. Bd. Agr. (London), Supplement, p. 15–37. Nov., 1911.

174. WOOD, T. B., and STRATTON, F. J. M. The interpretation of experimental results. *In* Jour. Agr. Science, 3:417–440. 1910.

175. WOODS, C. D. Field experiments. Maine Agr. Expt. Sta. Bul. 224. 1914.

176. WRIGHT, SEWALL. Correlation and Causation. *In* Jour. Agr. Res., 20–7. 1921.

177. ZAVITZ, C. A. Care and management of land used for experiments with farm crops. *In* Proc. Amer. Soc. Agron., 4:122–125. 1912.

REPORT OF THE COMMITTEE FOR THE IMPROVEMENT OF LABORATORY WORK IN THE INTRODUCTORY COURSE IN FIELD CROPS[1]

In the beginning the Committee meets the following predetermined conditions:

1. In nearly all colleges the introductory course in field crops aims to instruct in (a) the best practices for local production and in (b) matters more technical or cultural. The two objectives are of course interrelated, inseparable and mutually dependent for their interest and value; nevertheless practical instruction is generally of primary importance.

2. All male agricultural students are required to take this course (it may be divided into grains and forages, given in separate semesters); or a majority of students take it by choice.

3. Although many students take advanced courses in field crops, by election or requirement, the majority take only the introductory course. There are only rare exceptions to this condition.

Therefore this study must begin with the understanding that in nearly all colleges of agriculture the majority of students receive their only systematic training in field crops from an introductory course mainly in practical production. Whether this truly indicates the best possibilities for instruction in field crops or is simply the result of curricular limitations are questions which may not be appropriately discussed at this time. The situation must be accepted and its influence upon the nature of the problem recognized.

THE TYPES OF LABORATORY STUDIES AND THEIR RELATION TO LECTURES

Two clear types of laboratory studies may be defined. One type deals with additional subjects which are less adapted to treatment from the lecture chair and thus is a complement of the lectures in rounding out the course as a whole. Its total value bears the same relation to the total value of the lectures that one complete lecture bears to another. Each—the lecture or the laboratory study—is complete in itself and is related to the other only in a general sense. The other type supplements lectures on the same subject or makes applications of them. Its total value bears the same relation to the total value of the lectures that one part of a coherent lecture bears to another part. They—the lecture and the laboratory study—are

[1]Presented at the annual meeting of the society held in Chicago November 12, 1923, by the chairman of the Committee.

in this case two parts of the same thing and are mutually dependent and mutually indispensable.

But it does not follow that a teacher must employ exclusively one or the other of these types of laboratory study for the best practical results. Both types may be used in the same course if desired. Nor is it even necessary that every lecture have a laboratory counterpart. Some lectures are complete in themselves or their subjects are unadapted for laboratory study under ordinary circumstances.

As a general consideration on this point, the Committee will presume to state two maxims: (a) the profitable utilization of local facilities and resources is often more important than consistency in a given scheme of instruction; and (b) when the lectures and the laboratory study are coordinated, the laboratory period should be spent in emphasizing only the salient points of the lecture.

THE PREFERABLE TYPE OF LABORATORY STUDY FOR AN INTRODUCTORY COURSE IN FIELD CROPS

What should be the type of laboratory study for an introductory course in field crops whose main purpose is to give to the majority of its students the only systematic training which they are likely to receive in this subject? Clearly the course, as a whole, must be practical. To be practical it must make applications. Clearly the laboratory period is the proper time to make these. Therefore the type of laboratory study which coordinates closely with the lectures and makes applications of their salient points is preferable. It is ideal in any course with practical objectives.

Necessarily the salient points of such a course vary, with the emphasis on principles or factors which are concerned with local crops and local practices and are therefore to some extent locally determined. When laboratory studies are coordinated with lectures a variation in one is paralleled in the other. Therefore no course plan for either can be universally followed in detail and serve most effectively the great variety of local interests.

But many principles or factors in crop production are everywhere recognized and some of them are suitable for study in the laboratory of an introductory course. The Committee will not outline such a study, for its purpose is to suggest suitable material rather than to recommend a procedure for its use. Hence only the following subjects are named as being those which are important for laboratory study nearly everywhere.

The distribution of crops.—A brief study of the relative areas and locations of important crops.

Varietal adaptation.—Varietal identification, the laboratory counterpart of this principle, is highly important and demands important attention.

Good seed—A very broad factor whose study is well adapted to the laboratory period; including identification, analysis of quality, practice in judging quality, and the practices in selecting, storing, and treating seed.

Seeding practices, harvesting, hay making—Important factors whose adaptation to laboratory study is seasonal and dependent upon field facilities.

Ensilage—A subject almost universally important, for which an effective laboratory study is easily devised.

Plant association and competition, management of meadows and pastures, crop rotation—Highly important factors, excellent for field study when facilities are adequate.

Weeds, diseases, insects—Important factors whose recognition and practical control are well adapted and appropriate for laboratory study, either indoors or afield; provided the study is restricted to the most important enemies of local crops.

Crop grading—Everywhere the grading of one or more crops—grain, hay, cotton, potatoes, etc.,—provides important subjects for laboratory study which, in spite of mechanical difficulties, should receive appropriate attention.

Of course, this list by no means includes all subjects suitable for laboratory study. It simply sets up a group of conventional and highly important subjects whose lecture coordinates are found in nearly all well developed courses. They alone can furnish, if necessary, abundant material for a full laboratory course; for some of them can be extended very broadly. Local studies or studies provided only by extraordinary circumstances may be added when important or convenient.

SOME NEW MATERIAL AND A NEW METHOD OF LABORATORY STUDY

Neither the material nor the method which is now to be proposed is actually new, except in usage. Respectively, one is commonplace and the other almost obvious; but together they make a new combination. This report has already (a) indicated a preference for a type of laboratory study which coordinates closely with the lectures and makes practical applications of their salient points and (b) suggested a list of subjects which doubtless have lecture coordinates in nearly all introductory courses. There is now suggested a medium

through which these and other subjects can be studied with increased efficiency.

Take the questions asked by farmers in correspondence, select and classify them according to laboratory subjects, and present them to the class as illustrative material. Briefly the idea is—teach laboratory subjects partly through the medium of practical farm problems. Use the problem as an aid in the practical application of a salient point. For example, if seed storage, weeds, or hay making are being studied one can (a) greatly enliven class interest by stating farm problems common to these subjects or (b) assign to the student actual problems in the subject under study. Or, both can be done. At least one member of the Committee has undertaken such a systematic use of actual farm problems, with the most satisfactory results. The students at once begin to think in terms of crop production problems. What to do and how to do it? Thus an intelligently curious state of mind is developed, which is the great desideratum good teachers sometimes dream about.

Even the teacher himself sometimes is not without benefit from the use of this material, for he may gain new points of view or find new emphasis of old ones. But he must avoid the common liability of all problem methods of study to one thoroughly bad condition, namely, an indigestion of practical facts, which leaves the student without systematic knowledge of the subject itself. The teacher will avoid this when he subordinates the problem to the subject—makes the problem merely an illustrative case. He must make the discussion or the solution of the problem not an end in itself, but merely a means to an end. This is analagous to the case method of teaching law.

THE USE OF BOTANY

However, not all laboratory subjects can be properly studied through the medium of farm problems Some present numerous technical details and so require a systematic, technical analysis for good understanding of them. Most of this kind of subjects are botanical in character and are concerned principally with the identification of varieties of crops. They must therefore be studied by taxonomic methods.

This brings up a much mooted question among the makers of field crops laboratory outlines. How much botany? If students came to these courses with a fair working knowledge of the morphology of crops plants the answer would be easier. But more commonly they seem to lack even the rudiments of this knowledge. Perhaps it was not emphasized in their botany course, although it is by far the

most important botanical equipment for the elementary study of field crops. Perhaps it cannot be emphasized without destroying the symmetry of the conventional course in botany, in which case it will be well to sympathize with the botany teacher's ideals and to accept the situation as it stands.

Under these circumstances students must first review the essential morphology of crops plants and be taught how to use it; this to be followed by practice in identification, determination of botanical groups, or whatever the application may be. But isn't this about enough? Is there not a tendency to study crops botany to the exclusion of subjects more important for the majority of students, who are, as has been said, taking their only course in field crops? This is wrong, of course. Even to set up crops botany as a definite subject for study in a field crops laboratory, rather than to use it distinctly as a means of studying a principle or factor in crops production, is another proceeding whose propriety is at least debatable. Aside from considerations of proportion and propriety, there is nothing so deadening to the average student's interest in the whole course as an overdose of botany. His primary object is to know how to grow crops, not how to draw them. It should be said, however, that there can be no objection to a reasonable use of drawing as a method of analysis. The argument is against the incompetent teacher who exercises his students in botanical drawing because he can think of nothing better: while all around him, though he does not see it, is a wealth of important subject matter.

The Committee cannot answer completely the question it has raised. Indeed if there really is an answer it is only the generalization that the best use of crops botany is in the direct solution of such definite problems of crops production as are in themselves suitable for study in the laboratory of our introductory course. Let the teacher first carefully choose the problem or unit of knowledge which his class is to solve or acquire; let him state the problem or outline the unit; then let the class, with botany as an instrument, proceed to the solution or acquirement. The teacher should tell his class where it is going and give it the means to get there.

If this suggestion is clear, it covers the case. It should be emphasized, however, that this discussion applies only to the introductory course; such an introductory course as must be taught under the predetermined conditions mentioned in the beginning of this report. There are, to be sure, additional necessities for the use of botany in advanced studies of forages and cereals, and no one will belittle these in their reasonable proportions.

THE FIELD LABORATORY

The chief difficulty in teaching field crops is the lack of live illustrative material during most of the term. Seeds and plant specimens cannot take the place of growing crops, though used ever so ingeniously. Imagine, if you can, a course in live-stock judging illustrated only with stuffed animals!

But although in the nature of things this handicap cannot be completely removed, it can in a large measure be offset by adequate field facilities and the concentrated use of them at opportune times. Ample facilities for the production of specimens should be provided. But of even greater importance are facilities for illustrating cultural methods, or actual practices. These are indispensable if students are to achieve a real degree of craftsmanship, in understanding if not in actual skill. Even the most sound and complete verbal discussion of the advantages of a given practice is inadequate for a student who cannot visualize the practice itself. Imagine the costly mistakes of a poultryman who had been instructed only verbally in poultry practice! The Committee does not share the state of mind of a speaker who not so long ago questioned why field crops courses were so bad. Rather it is surprising that they are so good.

The teacher is fortunate who, in addition to his field laboratory, has the opportunity to give his class at least some elementary ideas of the methods and significance of field experimentation. A good teacher can make any plot in an experiment station field yield to his class something toward the development of a principle or factor, the solution of a problem, or the illustration of an idea. Simplicity is necessarily and desirably the keynote of this type of instruction. It should be stated in simple, practical terms what the experiment is designed to find out, how the search is being made, and what is the probable usefulness of what may be found. Problem, method, application. If it is thought that there can be found in an experiment station field nothing valuable for an elementary class, there should be considered the example of the great Aggasiz who, for final proof of a graduate student's mastery of his subject, would require him to write a child's story from his scientific treatise. Elementary students may be given much valuable instruction in an experiment station field; and in a few of them an ardor for investigation may be stimulated.

The tremendous value of the field laboratory should be realized; no effort to secure it for our students should be spared. They are as much entitled to its advantages as students or animal husbandry or dairying or poultry are entitled to the splendid equipment of

these branches. It should be the favorite log of the agronomic Mark Hopkins.

FINAL STATEMENT

The Committee has endeavored: (a) to present an analysis of laboratory studies for an introductory course whose nature is partly predetermined; (b) to suggest sound material for such studies; and (c) to present good reasons for its use. The suggestion of details of either material or procedure has been avoided, because of the belief that on a common basis the individual teacher can best develop his laboratory work as an integral part of the kind of course which he wishes to give or is influenced to give by his consideration of institutional policy. He may focus his course upon local objectives or he may give it a scope as broad as the whole country. To either procedure, the Committee's considerations and suggestions are applicable.

The question of the relation between this report and a previous report by the Committee on lectures may arise. They are both perfectly related and perfectly independent. A laboratory outline may be based on the salient points of the lectures (note the lecture details, Jour. Amer. Soc. Agron. 14:129 to 134); the ideas in the present report may be utilized to coordinate with an individual lecture outline of your own; the substance of both reports may be coordinated.

If there might now be expressed in a word the soundest philosophy on which to base the instruction of an introductory class in field crops, whose majority will probably receive no further systematic training in this subject, this word would be—*application*. Avoid teaching merely theoretically or merely scientifically about a thing, to such a class; rather teach the thing itself. Employ a plenitude of theory and science, to be sure; but bend it hard in the service of practical objectives.

Respectfully submitted,
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EDAPHOLOGY[1]

T. L. LYON AND H. O. BUCKMAN[2]

The body of knowledge relating to the nature and properties of soils is fast crystallizing into a science. Like many other sciences, its component parts have resulted from the application of several older sciences to the study of the material with which it deals. The chemist, the geologist, the physicist, and the microbiologist have all been contributors to the study of soils. In enlisting the services of a number of older sciences, this study resembles some of the other recently established sciences. Because the plant physiologist may attack his problem in research provided with the tools and methods of chemistry, he is none the less a botanist. The anthropologist may bring to his subject a training in one or more of many sciences.

There is no rule that marks the point at which a subject ceases to be a branch of each of several sciences and becomes a science in itself. Probably the boundaries are determined by the men who do the work. Formerly the chemist dealt with the composition of soils, the geologist with the decomposition of rock and the formation of soil, the bacteriologist with the activities of the germs inhabiting the soils. In each case their work was regarded only as an application of the older science to an uncharted and unassigned field.

The beginnings of a science may possibly be considered to be made when men devote their entire time to that subject, provided, of course, that it falls within the definition of a science in other respects. In this sense the study of soils may be called a science, for most agricultural colleges now have men who devote their entire time to that subject.

An important step towards the formation of a science was affected when a classification of soils was attempted, for with it comes the differentiation which, altho it may not be perfect, gives opportunity for the study of individual soils, necessitates a terminology which promotes exactitude, and tends to obviate confusion by distinguishing between the soils on which different investigators may be working. A classification of the subject matter of a science is one of the early movements in its development.

Assuming that we have at least a budding science based on the knowledge that has accumulated regarding the nature and properties of soils, it then becomes desirable to find a name by which to dis-

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tinguish it from other sciences. Obviously the name should indicate something of the nature of the science and if it conforms with the nomenclature used for designating other sciences so much the better. Preferably it should be one word only. There are not many sciences, possibly none, with a two- or three-word name.

The term agronomy was the result of a happy thought on the part of someone. It has been useful and will continue to be, for it covers the study of soils and field crops which will doubtless continue for a long time to form a unit in the organization of technologists in those fields. It is, however, too broad a term to be applied to the study of soils alone. Soil technology and soil science have served a useful purpose. They have the advantage of being comprehensible to the man in the street and the disadvantage of consisting of two words. They both possibly fall somewhat short of implying the end and aim of the study of soils by the agronomist.

In an endeavor to find a term that will consist of one word and also convey an agronomic implication the word "edaphology" has been proposed. It is derived, of course, from *Edaphos*, the Greek word meaning ground, foundation, base, etc. The term edaphic is in use by botanists to denote the relation of the plant to its soil environment. The agronomist's interest in the soil is based on its agricultural utilization. It seems fitting that the word used to represent the study of soils should connote the plant relationship. This term has the advantages enumerated above. It has the disadvantage of being new and perhaps somewhat cumbersome.

Another use of the same root has been suggested in the term "edaphics" which has brevity to commend it. Also, the adjective "edaphic" is less awkward than "edaphological." On the other hand, "edaphology" proclaims the science while "edaphics" does not necessarily do so.

The terms "podology" and "agrogeology" are already in use. They are somewhat more restricted in meaning than are the two terms previously mentioned. They have been used to designate the classification of soils rather than the entire field of soil science. Neither connotes the plant relationship.

Whatever may be the advantages and shortcomings of any of these terms, there can be no doubt there is need for a word that will have the following meaning—the science of the nature and properties of soils in their relations to plant growth.

AVAILABILITY STUDIES UPON HIGH POTASH NITRATE[1]

R. V. ALLISON[2]

While "High Potash Nitrate" has not, as yet, become prominent as a source of plant food, several thousands of tons are produced annually from the "calische" of the Chilean nitrate mines and distributed in the fertilizer markets. Since it is now readily obtainable, a series of tests of the availability of the nitrogen and potash of this material seemed worth while, and have been carried out under both greenhouse and field conditions. While the detailed results of these studies need not be presented here, sufficient data will be given to indicate the nature of the crop response to this material as compared with that from the nitrogen and potash in other products.

In appearance the commercial salt is quite similar to the well-known sodium nitrate, though it is considerably lighter in color. The material used in these studies contained 15.0% potash and 15.6 percent nitrogen as nitrate as determined by the Devarda alloy method.

GREENHOUSE STUDIES

Several different studies in the greenhouse showed essentially the same results, hence only the rye series with a Sassafras gravelley loam soil will be presented.

The soil used in this study had been cropped in cylinder experiments for fifteen years and during this time had received no commercial fertilizers or manure. The maximum water holding capacity of the soil by the Hilgard method was found to be 36.9%. The cultures were prepared with four kilograms of the soil per pot (glazed stoneware jars) and planted to rye on June 28th. All cultures were prepared in duplicate and the treatments made as outlined in Table 1, where also the relative dry weights of the crop are recorded. The rye was harvested on August 19th and followed by popcorn. The detailed data for the latter crop are omitted from this report.

The results set forth in the Table 1 show that the response of the plants to both the potash and the nitrogen of this material compares favorably with that to the combination of sodium nitrate and potassium sulfate. Thus, while there is but slight response to phosphate (106, as compared with the check) or potash (106 and 109) alone,

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the response to nitrogen is marked (155 and 204). Phosphate, however, gave added values when applied with nitrate (155 and 204 without phosphorus versus 134 and 151 with it.) In support of the statement above as to the efficiency of the high potash nitrate, it is to be noted that in the more balanced applications of all the elements in quantities of 2X for nitrogen and potash, the combination of sodium nitrate and potassium sulfate gave a relative yield of 289 while with the high potash nitrate it is 291.

TABLE 1.—*Comparative response of rye to fertilizer treatments with various sources of nitrogen and potash including "High Potash Nitrate."*

Culture No. (In duplicate)	Treatment	Relative dry weight of crop
1	Check (Nothing)	100.0
2	Phosphoric acid*	106.7
3	(X) Sodium nitrate**	154.8
4	(2X) " "	203.8
5	(X) Potassium sulfate***	109.2
6	(2X) " "	106.0
7	P_2O_5* and (X) $NaNO_3$**	206.1
8	" " (2X) "	232.0
9	" " (X) K_2SO_4***	134.4
10	" " (2X) "	151.9
11	" " (X) $NaNO_3$ and (X) K_2SO_4	236.6
12	" " (2X) " " (2X) "	289.0
13	" " (X) HIGH POTASH NITRATE	225.3
14	" " (2X) " " "	291.2
15	" " (2X) N. as ammonium sulfate	287.7
16	" " (2X) N. as dried blood	101.7
17	2–8–2 } 600 lb. per acre ($NaNO_3$ and K_2SO_4 as basis)	155.7
18	4–4–4 }	174.6
19	2–8–2 } 600 lb. per acre (HIGH POTASH NITRATE as basis)	174.6
20	4–4–4 }	234.7

The maximum production is to be found in the potassium nitrate cultures with a comparative yield of 291 as against 289 and 287, respectively, for sodium nitrate and ammonium sulfate. Though they are in this instance essentially checks, as in all work of this nature, such results can not be regarded as definite responses. In this connection, it might be noted that if the rye crop is considered in connection with the corn which followed, the high potassium nitrate is considered superior to any of the salts used, particularly as compared to the ammonium sulfate; since, with this salt, the response of the corn was apparently very low.

The differences in the yield between the 2–8–2 and 4–4–4 mixtures is also of interest, appreciable differences apparently existing between the high potash nitrate and the mixture of sodium nitrate and potassium sulfate when employed in these formulas. Thus, with the 2–8–2 versus the 4–4–4 with sodium nitrate and potassium sulfate as a basis, the percent of gain over the check is 56 and 75 respectively;

while with high potassium nitrate in the same relation, it is 74 and 134 respectively. This same relation in the application of the different combinations is to be found in the case of the corn crop which followed, altho the difference between the sodium nitrate and potassium sulfate as compared to the high potassium nitrate is less marked except in the comparison of the 4-4-4 mixtures.

A further interesting comparison is that of the response of the rye cultures receiving cow manure with that of the corn crop which followed. In this case it was found that while the gain in the rye crop over the check cultures is not appreciable as the result of this application (102), for the corn it was large (306), thus indicating, the effect of time upon the availability of the organic nitrogenous material.

FIELD STUDIES

The following tests of the effectiveness of high potassium nitrate under average field conditions were carried out upon land which had not been previously used for experimental purposes. A series of plots was laid out on a young meadow. The arrangement of treatments was as outlined in Table 2 where, also, the yields are reported, calculated to the acre basis.

The farm upon which these tests were conducted lies about 1½ miles west of New Brunswick and the soil is derived from red shale a distinct Penn loam type. Through consistent applications of farm manure and artificial fertilizers, the soil is in a fair condition of

TABLE 2.—*Fertilizer treatment and yields of hay, field trials.*

Plot number	Treatment	Weight of hay (pounds per acre)
1	Check (no treatment)	2450
2	Phosphoric acid (400 lb. per acre)	2520
3	(X) Muriate of potash (50 lb. per acre)	2590
4	(X) Sodium nitrate (160 lb. per acre)	3990
5	P_2O_5 and (X) KCl	2785
6	" " (X) $NaNO_3$	4480
7	" " " " and (X) KCl	4480
8	" " (X) HIGH POTASH NITRATE	4235
9	2-8-2 } 600 lb. per acre (Based on $NaNO_3$ and K_2SO_4)	3185
10	4-4-4 }	3570
11	Check (No treatment)	2415
12	Phosphoric acid (400 lb. per acre)	2170
13	(2X) KCl (100 lb. per acre)	2450
14	(2X) $NaNO_3$ (320 lb. per acre)	3990
15	P_2O_5 and (2X) KCl	2485
16	" " (2X) $NaNO_3$	3780
17	" " (2X) KCl and (2X) $NaNO_3$	4025
18	" " (2X) HIGH POTASH NITRATE	4270
19	2-8-2 } 600 lb. per acre (Based on HIGH POTASH NITRATE)	2660
20	4-4-4 }	3605

productivity. This information will show that the soil used in this work was in no way below normal in productivity.

The plots as indicated in the table were measured to represent 1/100 acre with an intervening space of two feet. Their arrangement was from 1 to 20 in the order indicated. The application was made on June 17 at which time the growth upon the ground was largely clover and timothy, though a considerable number of weeds appeared later in the season.

A study of the table will show that the response has been to nitrogen only. For this reason, no conclusions may be drawn as to the availability of the potash on the High Potassium Nitrate. The response to nitrogen is shown effectively by averaging the results of all plots not receiving nitrogen and those receiving it, as shown in Table 3.

TABLE 3.—*Average yields of hay from plots receiving nitrogen contrasted with those receiving no nitrogen*

Plot Numbers		Fertilizer Treatment	Average yield of plots indicated (lb. hay per acre)
1 and 11		Check (no treatment)	2432
2 and 12	No nitrogen	P_2O_5	2483
3 and 13		K_2O	
5 and 15		P_2O_5 and K_2O	
4 and 14	Nitrogen	$NaNO_3$	4144
6 and 16		$NaNO_3$ and P_2O_5	
7 and 17		$NaNO_3$ and P_2O_5 and K_2O	
8 and 18		P_2O_5 and High Potassium Nitrate	
9 and 19		2–8–2 (600 lb. per acre)	2922
10 and 20		4–4–4 (600 lb. per acre)	3587

It appears that in the (2X) applications (plots 13 and 19) the potash as muriate depressed the yield somewhat. It is further shown that the double applications of nitrogen did not increase the yield over those from the (X) applications, either on the High Potassium Nitrate plots or those receiving sodium nitrate and potassium sulfate. A comparison of the High Potassium Nitrate plots (8 and 18) shows that the average (4272) is quite as good, in fact is identical with that of 7 and 17 receiving sodium nitrate and the muriate of potash.

A second series of plots (twelve in number) were laid out on another meadow in a similar manner to study the effect of the treatments upon the development of the aftergrowth. Because of the extremely dry season there was but scant growth. It was again apparent, however, that the response was due to the nitrogen treatment.

SUMMARY

Experimental studies upon the availability of the nitrogen and potash of High Potash Nitrate have been carried out under both green-house and field conditions.

The results in pot culture indicated the value of the nitrogen and potash of this compound as being fully equivalent to that derived from sodium nitrate and potassium sulfate. Because of the fact that the field plots responded strongly to applications of nitrogen and not at all to potash, it may be assumed that the nitrogen of the High Potash Nitrate was as effective as that of sodium nitrate.

THE RELATIVE EFFECTS OF FOREIGN POLLEN UPON THE KERNEL WEIGHT OF COMMERCIAL VARIETIES AND SELFED STRAINS OF CORN[1]

T. A. KIESSELBACH AND G. C. COOK[2]

The object of this investigation has been to compare the immediate effects of fertilization by foreign pollen upon the kernel weights of selfed strains, commercial varieties, and various botanical types of corn.

By pairing varieties differing in endosperm or aleurone color under control conditions, the pure and hybrid kernels may be distinguished by color, because of changes resulting from the secondary fertilization of the endosperm nucleus in the embryo sac.

HISTORICAL

McCleur (5)[3] appears to have been the first to report on the immediate effect of foreign pollen upon the kernel weight of corn. Using five ears of sweet corn pollinated with a mixture of sweet and dent pollen, he found an increase in weight of hybrid over pure kernels ranging from 19.47 to 31.82 percent for the different ears.

Collins (2) secured an increase of 16 percent for hybrid kernels on an ear of Chinese corn fertilized in part with pollen from a dent variety. Roberts (7) also observed a large increase for kernels of this variety fertilized by foreign dent pollen. Collins and Kempton (3) reported an increase in kernel weight ranging from 3 to 21 percent for eleven crosses in which ears were fertilized with a mixture of pollen.

Wolfe (8) offers the results of 37 crosses as evidence of marked effects on kernel weight resulting from the fertilization of commercial varieties with pollen from other varieties. Wolfe concludes that

[1]Contribution from the Department of Agronomy, Nebraska Agricultural Experiment Station, Lincoln, Nebraska. Received for publication November 20, 1923.

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[3]Reference by number is to "Literature cited," p. 36.

"in the crosses obtained, 56.8 percent produced profitable increases in yield (weight of kernels) and in 13.5 percent the increase was slight. In 24.3 percent of the crosses, the decrease was marked and in 5.4 percent it was slight. The largest increase was 16.04 percent, and the greatest decrease 13.45 percent."

Carrier (1) concluded from his own investigations and those of others that a decided increase in the kernel weight of commercial varieties of corn results from the stimulus of hybridization.

East and Jones, (4) reported the immediate effect of reciprocal crosses between Illinois Low Protein and Stadmueller High Protein corn. Sixteen plants of each variety were pollinated with a mixture of their own individual pollen and that from a plant of the opposite variety. The hybrid kernels averaged 19.7 percent heavier than the selfed.

Previous results reported by this Station (Kiesselbach, 6) include a five year test in which a 0.32 percent increase was secured for the hybrid kernels on wind fertilized ears grown in a field of commercial Hogue Yellow Dent and partially fertilized by pollen from an adjoining field of Nebraska White Prize. The immediate effect of crossing on kernel weight varied in the different years from an increase of 1.8 percent to a decrease of 0.7 percent. About 200 ears were represented in this test each year. In 1921 seven crosses between commercial varieties showed an average increase of 0.22 percent from foreign pollen, ranging from an increase of 1.3 percent to a decrease of 1.7 percent. In the same year 30 ears of long time selfed strains of two varieties of dent corn were partly fertilized with composite pollen of sister plants from their own strains and partly by foreign dent pollen. Hybridization increased the average kernel weight 11.2 percent.

EXPERIMENTAL

The results recorded in the accompanying table were all secured from controlled hand pollinations in 1922. Bagged shoots were pollinated with mixtures of pollen obtained from a number of other plants of the same variety or strain and a number from another variety chosen so that the resulting hybrid kernels could be distinguished by their color. Since selfing was not permitted, the pure kernels obtained should have a genetic constitution equivalent to that which might obtain under ordinary farm field conditions, except for the small amount of selfing which occurs under wind pollination. Under Nebraska conditions this has been found to be less than 1 percent. (Kiesselbach, 6).

TABLE 1.—*The immediate effect of foreign pollen upon the kernel weight of selfed strains and commercial varieties of corn, 1922*

Ear parent	Pollen parent	No. of kernel pairs	Moisture-free wt. of 100 kernels: Actual, Pure Grams	Actual, Hybrid Grams	Relative, Pure Pct.	Relative, Hybrid Pct.
		Selfed strains of dent corn				
Hogue Yel. Dent, No. 12	Nebr. White Prize	40	20.74	24.06	100	116.01
" " " 725	" " "	205	15.85	19.00	100	119.87
" " " 726	" " "	346	19.87	20.85	100	104.93
" " " 745	" " "	510	17.54	20.33	100	115.91
Nebr. White Prize 663	Hogue Yel. Dent	230	18.99	20.73	100	109.16
" " " 676	" " "	140	13.48	14.47	100	107.34
" " " 680	" " "	160	20.70	22.69	100	109.61
" " " 690	" " "	170	18.97	21.32	100	112.39
Average					100	111.90
		Commercial varieties of dent corn				
Martens' White Dent	13 varieties	3255	19.92	19.91	100	100.00*
Substation W. Dent	19 varieties	6160	21.78	21.82	100	100.18
U. S. Selection No. 133	5 varieties	1837	23.86	23.97	100	100.46
Hogue Yellow Dent	24 varieties	6922	22.68	22.71	100	100.13
Iowa Gold Mine	15 varieties	2568	22.79	23.01	100	100.97
University No. 3	10 varieties	1935	22.69	23.02	100	101.45
St. Charles White	10 varieties	2319	22.33	22.22	100	99.51
Iowa Silver Mine	11 varieties	1858	22.54	22.35	100	99.16
Nebraska White Prize	18 varieties	6598	21.30	21.19	100	99.48
Boone County White	8 varieties	1744	22.44	22.37	100	99.69
Rapid Yellow Dent	12 varieties	1963	22.18	22.33	100	100.68
Improved Leaming	13 varieties	4303	22.01	22.22	100	100.95
Average					100	100.24
		Commercial varieties of various botanical types of corn.				
Dent. Minnesota No. 13	White Australian Flint	322	23.53	23.84	100	101.32

Rustlers W. Dent	Gehu Flint	363	26.22	25.92	100	98.86
Substation White	King Philip Flint	236	24.42	24.63	100	100.86
Nebraska W. Prize	King Philip Flint	346	18.54	18.65	100	100.59
University No. 3	Navajo Flint	48	22.55	22.65	100	100.44
Nebraska W. Prize	Zea Ramosa	86	20.00	20.02	100	100.10
Nebraska W. Prize	Yellow Rice Pop	159	19.85	19.59	100	98.69
Hogue Yel. Dent	Blue Mexican Sweet	137	23.93	23.66	100	98.87
Substation White	Golden Bantam Sweet	154	23.39	23.10	100	98.76
Hogue Yel. Dent	Red Flour	332	20.81	20.65	100	99.23
Substation White	Blue Flour	138	22.32	22.66	100	101.52
Substation White	Red Flour	204	21.56	21.28	100	98.70
U. S. Selection No. 133	Red Flour	451	23.40	23.35	100	99.79
Average					100	99.83
Sweet.						
Golden Bantam	Blue Mexican Sweet	287	21.04	21.31	100	101.28
Country Gentleman	Blue Mexican Sweet	113	12.72	13.06	100	102.67
Average					100	101.97
Blue Mexican	U. S. Selection No. 133 Dent	82	21.88	26.60	100	121.57
Golden Bantam	U. S. Selection 133 Dent	272	19.01	24.39	100	128.30
Country Gentleman	Calico Dent	144	8.21	9.39	100	114.37
Country Gentleman	Red Flour	101	10.22	11.59	100	113.41
Cluntry Gentleman	Blue Flour	54	13.94	16.39	100	117.58
Country Gentleman	White Pearl Pop	50	9.16	10.48	100	114.41
Average					100	118.27
Flint.						
White Australian	Golden Bantam Sweet	175	21.34	21.05	100	98.64
White Australian	Minnesota 23 Dent	215	23.38	24.21	100	103.55
Rhode Island	U. S. Selection 133 Dent	502	25.91	27.37	100	105.53
King Philip	Nebr. W. Prize Dent	261	21.63	21.71	100	100.37
Gehu	Rustlers White Dent	57	13.49	13.46	100	99.78
Average					100	101.59
Pop.						
Yellow Rice Pop	Red Rice Pop	479	12.03	12.04	100	100.08

*Average of 13 combinations with other varieties.

In order to reduce the effects of plant individuality, the pollination of 15 ears was undertaken for each combination. From 3 to 10 well-filled ears showing both pure and hybrid kernels were thus produced for most crosses. The immediate effect of hybridization was determined by contrasting the composite weight of hybrid kernels with adjacent pure kernels. Pure and hybrid kernels were removed from the ear for this test only when they occurred in pairs and as far as possible place effect on the ear was further avoided by taking the pure kernels alternating on the butt and tip side of the hybrid kernels. The results obtained from the various different types of corn are shown in Table 1.

Selfed Strain Hybrids

Eight combinations of selfed strains fertilized by foreign dent pollen gave an average increase in kernel weight of 11.9 percent. This increase ranged from 4.9 to 19.9 percent for the different strains. This increase in weight can be accounted for only by increased hybrid vigor or heterosis due to crossing. This corresponds to the vigor exhibited by hybrid plants in comparison with their pure line parents.

Hybrids between Commercial Dent Varieties

Twelve standard commercial varieties of dent corn, differing in vegetative characteristics, were used as the ear-bearing parents. From five to twenty-five varieties were crossed on each of these, making a total of 158 variety combinations. An average increase of 0.2 percent in the kernel weight of these varieties resulted from hybridization.

The variation for the twelve varieties in response to foreign pollen ranged from a decrease of 0.8 percent to an increase of 1.0 percent. It may be concluded that the kernel weight of fully heterozygous commercial dent varieties is but little influenced by fertilization with pollen from other dent varieties.

Dent Varieties crossed with other Botanical Types

Thirteen crosses of commercial dent varieties by other botanical types, including sweet, flour, flint, and pop resulted in an average decrease of 0.2 percent in the weight of hybrid compared with pure kernels. The results varied from a decrease of 1.3 percent to an increase of 1.5 percent. In view of these small effects we may conclude that all of the botanical types tested are practically equal in their effectiveness as pollen parents in producing grain of normal weight.

Flint and Pop Crosses

Flint and pop varieties responded to foreign pollen to about the

same extent as did dent corn. A pop variety gave an increase in kernel weight of 0.1 percent when fertilized by another pop variety. Five flint varieties gave an average increase of 1.6 percent when cross pollinated and ranged from a decrease of 1.36 percent to an increase of 5.6 percent.

Sweet Corn Hybrids

Two commercial sweet corn varieties gave an average increase of 1.97 percent in kernel weight when fertilized by foreign sweet corn pollen. The response due to heterosis appears to be no greater for sweet corn than for the other botanical types. A very marked increase in the kernel weight resulted, however, from pollinating sweet corn with pollen from types having starchy endosperms. This increase ranged from 13.4 percent for a sweet by flour cross to 28.3 percent for a sweet by dent cross. The six sweet by starchy corn crosses gave an average increase of 18.3 percent in kernel weight due to the immediate effect of crossing.

These great increases for commercial sweet varieties are not to be accounted for by heterosis. They are due, rather, to the dominant genetic influence of the starchy character which was transmitted thru the male gamete, thereby transforming the sweet endosperm into starchy endosperm. Starchy endosperms have the capacity not possessed by sweet kernels to precipitate starch progressively thruout their growth. This permits a greater osmotic intake and storage of substance which is very apparent in the mature kernels. The sweet kernels are translucent and shrunken or wrinkled compared with the smooth, plump and starchy hybrid grain resulting from cross pollination.

These studies fail to show the marked effects on kernel weight due to heterosis that have been shown by other investigators, when commercial varieties are fertilized by foreign pollen. This may be due to one or more of three causes: (1) A decided error due to place effect may result from the practice of comparing all pure and hybrid kernels on an ear, rather than comparing them in adjacent pairs. (2) Plant individuality may be a factor when results are based on single ears. (3) Varieties may differ in their heterozygosity and consequently in their response to foreign pollen.

SUMMARY

An increase in kernel weight of corn due to fertilization by foreign pollen may result from two causes: (1) heterosis and (2) a change in type of endosperm.

The increase from heterosis is very marked in the case of selfed strains amounting in these tests to an average of 11.8 percent for eight such strains.

The increase due to a change in endosperm type, which occurs with sweet corn when fertilized by a starchy type, is also marked. It amounted to an average of 19.9 percent for six such sweet-dent combinations. This increase may have been slightly modified by a change in heterosis since two commercial sweet corn varieties pollinated by other sweet varieties gave an increase of 1.9 percent in kernel weight.

Commercial varieties of corn, being heterozygous, respond relatively little to the immediate effect of foreign pollen as a result of heterosis. One hundred fifty-eight dent combinations on twelve standard dent varieties averaged an increase of 0.2 percent. Thirteen combinations of dent by other types, including flint, pop, flour, and sweet gave an average reduction of 0.2 percent for the weight of hybrid kernels.

Commercial varieties differ somewhat in the degree of response to foreign pollen, due probably to a difference in their heterozygosity. The extreme range of effect due to heterosis noted for more than 250 variety combinations made at this Station has been from a decrease of 2.3 percent to an increase of 5.6 percent.

LITERATURE CITED

1. Carrier, Lyman. A reason for the contradictory results in corn experiments *In* Jour. Am. Soc. Agron. 11:106–113. 1919.
2. Collins, G. N. A new type of Indian corn from China. U. S. D. A. Bur. Plant Ind. Bul. 161. 1909.
3. Collins, G. N., and Kempton, J. H. Effects of cross pollination on size of seed in maize. *In* Misc. Papers, U. S. D. A. Bur. Plant Ind. Circ. 124:10, 15. 1913.
4. East, E. M., and Jones, D. F. Genetic studies on the protein content of maize. *In* Genetics, 5:563. Nov., 1920.
5. McCleur, G. W. Corn crossing. Ill. Agr. Exp. Sta. Bul. 21. 1892.
6. Kiesselbach, T. A. Corn investigations. Nebr. Agr. Exp. Sta. Res. Bul. 20:83–90. 1922.
7. Roberts, H. F. First generation hybrids of American and Chinese corn. *In* Ann. Rpt. Am. Breeders Assn., 1911–1912. 8:374-375. 1912.
8. Wolfe, T. K. Further evidence of the immediate effect of crossing varieties of corn on the size of seed produced. *In* Jour. Am. Soc. Agron., 7:265–72. 1915.

PHYSICAL CHARACTERISTICS OF DISEASE-FREE SEED CORN[1]

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For many years investigations have been conducted in several states of the Corn Belt to show that corn is affected by rot diseases of the root, stalk, and ear. During the past seven years rapid strides have made been in the work, chiefly because of the active and effective cooperation of the agricultural experiment stations and other agricultural institutions with the United States Department of Agriculture.

On some farms, in many localities where scientific agriculture is practiced to the highest degree, such as growing of legumes, crop rotation, adding limestone and rock phosphate and other fertilizers to the soil, the increased quantity and quality of corn secured is not sufficient to justify this additional expense for materials and labor, if little thought is given to the seed corn planted.

METHOD OF OBTAINING DISEASE-FREE SEED CORN

"Disease-free" seed corn is the seed from ears tested on the germinators which show freedom from a number of the known corn diseases which cause slow and rapid rotting of the corn plant roots. These ears also show a strong and vigorous root system. In recent years, there has been an increasing demand for the individually-ear-tested disease-free corn. To assist in securing disease-free seed a corn testing laboratory was started. The germinating room in which the corn is tested has a capacity for testing thousands of ears at one time. The room is heated with steam and a thermostat automatically controls the temperature at the desired point day and night. Two electric fans are at one end of the room for drawing fresh air through at intervals in order to maintain proper humidity. Flats are used on which the kernels of corn are placed and kept in the germinator. Six kernels are taken from each ear, progressing spirally around the ear in removing them. They are then placed on a cloth and when the flat is filled another cloth is put over them, moistened, and taken into the germinating room. Here they are left for about six days at uniform temperature, and watered every day. The flats are then taken out of the room, the upper cloth removed and the entire root system of the kernels can be easily seen and the condition of each

[1]Contribution from the Illinois Seed Corn Testing Laboratory, Bloomington, Ill. Received for publication November 21, 1923.

[2]Proprietor.

ear determined. The system of records kept makes it possible to locate any lot or individual ear of corn in a few minutes.

SEPARATING THE DISEASE-FREE AND DISEASED SEED

Each lot of seed corn from the germinators is examined very carefully and divided into three parts: (1) disease-free ears; (2) slightly diseased ears; and, (3) badly diseased ears. When the six kernels of an ear show strong, vigorous germination and are free from any indication of disease, that ear is classed disease-free. If the kernels are of strong germination, but one or two of them show signs of a minor disease, the ear is classed as slightly diseased. If all six kernels show symptoms of rot diseases, even if the germination is perfect, the ear is classed as badly diseased and unfit for seed corn. These different grades are returned to the farmers with the suggestion to plant only the first two grades and to keep them separate so as to select seed corn the following year from the field planted with the disease-free seed.

OBSERVATIONS ON 4000 BUSHELS OF FARMERS' SEED CORN TESTED

During the winter of 1922–1923 approximately 4000 bushels of seed corn representing over 350 lots were individually ear tested in the laboratory. This seed corn came from practically every part of Illinois and several lots from Indiana. The seed was sent by good farmers and carefully selected so that the seed was representative of the type of ears used by all farmers. The writer personally examined every ear of seed tested on the germinators and recorded observations made of each lot of corn.

Of the 4000 bushels of seed corn ear tested, the viability (composite germination) averaged 96.5 percent: but 30 percent of the ears of this seed corn were badly diseased and discarded as unfit for seed purposes.

This 30 percent, or 1200 bushels of badly diseased seed, was sufficient to plant about 9600 acres of corn. If this acreage was planted with the diseased seed, the yield would have been reduced more than 50 percent and contained a high percentage of rotted corn. From these figures it is easy to understand why in unfavorable or even fair weather for corn there are many thin stands, large numbers of weak and stunted plants, stalks that are leaning down and broken, barren stalks and nubbins, chaffy, immature ears, and reduced yields.

The tables presented below show that the large, dull lemon yellow colored ears of rough or medium rough indentation should be discarded due to weak vitality, and also show a high percentage of disease.

Selecting this type of seed corn means considerable replanting in an unfavorable spring, or much rotted, moldy, and light shriveled corn in a late rainy fall.

For many years, opinions have been given regarding the best type of seed ear to select to secure the highest yields of corn. Some growers recommend a large ear of rough indentation, while others suggest a medium smooth type of ear. On the 4000 bushels of seed corn coming from many farmers and different localities, the writer carefully made the following observations and records to assist in determining the type of seed ear which exhibits more resistance to the various corn rot diseases, and consequently the type of ear which will produce the highest yields and best quality of corn.

PHYSICAL CHARACTERISTICS OF TESTED SEED CORN

TABLE 1.—*Data showing correlation of vitality, kernel color, and indentation, to the percentage of disease-free seed in seed corn.*

Percentage of ears testing disease-free	No. of lots tested	No. of bushels tested	Viability* of lots before separating the disease-free seed	Percentage of ears with kernel indentation		Percentage of ears with color variation	
				Rough	Smooth	Bright golden yellow	Dull lemon yellow
1–20	18	181	94.5	95.9	4.2	25.0	75.0
21–30	91	857	96.3	88.5	11.5	34.9	65.1
31–50	230	2699	96.9	40.5	59.5	76.9	23.1
51–over	19	152	98.2	16.7	83.3	94.4	5.6

*Average percentage composite germination.

INDENTATION OF SEED CORN

TABLE 2.—*Data showing relation of degree of indentation, viability and freedom from disease in seed corn*

Indentation	Average Viability	Percentage of ears testing disease-free
Rough	96.7	27.9
Medium rough	96.8	32.7
Medium smooth	97.1	42.7
Smooth	95.5	44.2

Table 1 shows that as the percentage of disease-free seed increased, the vitality of the seed increased as shown by the viability (composite germination). Likewise as the percentage of disease-free seed increased, the combination of smoother type ear with bright golden yellow color materially increased, while the combination of rougher type of ear with dull lemon yellow color showed a decided decrease. Most of the lots ranged from 31 to 50 percent disease-free, and in these, as in the lots with over 51 percent disease-free corn, it was observed

that the root systems were very vigorous and showed a low percentage of saprophytic molds. The percentge of such molds appeared high in the 1 to 30 percent disease-free seed. It is known that these molds indicate a weak seed very susceptible to the serious rot diseases.

Table 2 shows relation of the indentation factor to vigorous and disease-free seed corn. The greatest increase in disease-free seed was between the medium rough and medium smooth seed, and the strongest vitality was with the medium smooth seed. This applies to both yellow and white corn.

Luster of Seed Corn

Table 3.—*Data showing relation of luster to viability, freedom from disease and disease infection in seed corn*

Color	Percentage viability	Percentage of ears testing disease-free	Percentage of ears testing badly diseased
Very bright golden yellow	97.4	44.3	19.8
Bright golden yellow	96.9	38.7	28.4
Dull lemon yellow	96.9	30.9	32.8
Very dull lemon yellow	94.6	28.3	33.6

Table 3 shows that the degree of luster is an important factor in selecting good seed corn. Here again it appears that the very bright yellow color is an outstanding indication of vigor and high percentage of disease-free seed. This luster factor is also applicable to white seed corn, the pearly white being more desirable than the milky white colored ears.

SUMMARY

With the present day knowledge of seed corn, dependance should not be placed on the germination test alone, but more attention must be given to the quality of the seed.

Large rough seed ears which also show dull color should be avoided. These are usually late maturing, weak or badly diseased ears.

Mature, firm seed ears of average size, which show very bright color or luster, medium smooth indentation, and fairly good depth of kernel should be selected.

Such seed ears possess strong vitality and a high percentage of disease-free seed, and will withstand adverse weather conditions better, grow and mature more uniformly, and produce a higher yield and an excellent quality of corn.

THE EARLY HARVEST OF RUSTED MARQUIS WHEAT[1]

(A Preliminary Report)

T. E. STOA[2]

The stage of maturity for harvesting wheat is still a matter for frequent discussion. Whenever the natural physiological processes of the wheat are interfered with, a condition resulting from the development of stem rust, the question arises, should such grain be harvested before the full stage of maturity is reached?

THE NORMAL HARVEST

What is the proper stage for harvesting wheat that matures normally? The longer the growing season, the greater the yield. Thatcher (10)[3] observed "The average weight of the kernel would vary directly with the length of the development period, and the length of the period to be the determining factor in the final composition of the grain." Maturing of the wheat kernel is largely a process of translocation of foodstuffs already manufactured, particularly the carbohydrate materials. Saunders (6) found that the physiological processes which go on in the mature wheat plant are most active from 20 to 25 days before maturity, and that materials deposited at that time in the grain of the plant amounted to about 100 pounds per acre per day. He found that this rate increased until about 17 days before the usual harvest period, when the rate of activity remained about the same. From this point the amount of material deposited decreased and reached the zero point when the grain was considered ripe in the Ontario region. Saunders concludes that wheat might well be harvested several days earlier in Ontario, allowing the grain to finish ripening in the shock. The practice in Ontario, he states, is generally to allow the grain to stand a good deal longer than is the common practice in the Central Plains.

McDowell (5) found that, from the yield standpoint, the best results in harvesting Nevada wheats were secured when the kernels were in the very late dough stage, and difficult to break with the fingers.

The percentage of nitrogen material is greatest in the early stages of the wheat kernel. Carbohydrate materials increase more rapidly

[1]Paper read at the Western Agronomic Conference held at Bozeman, Mont., July 26–28, 1923. Received for publication November 26, 1923.

[2]Assistant Agronomist, North Dakota Agricultural Experiment Station, Fargo, N. D.

[3]Reference by numbers is to "Literature cited." p. 47.

in the later stages of the kernel development. The rapid translocation of carbohydrate materials is chiefly responsible for the reduction in percentage of nitrogenous substances. The absolute amounts, however, of all constitutents, including nitrogen compounds, increases up to the time of maturity.

It might be inferred that immature grain, richer in protein products, would mill a stronger flour. Such however, is not the case. The quality of the wheat for breadmaking improves with the maturity of the kernel. Stockham (9) observed that "On the average with all grades of flour the higher the percentage of protein the greater the strength up to a certain point. Beyond this in the harder classes there are indications of weakness." The kind of proteins is more important than the quantity. Too early cutting lessens the quality and the amounts of those forms of proteins most desired. Gluten content and loaf volume increases with the maturity of the wheat. The color of the resulting bread is better when the wheat is allowed to reach full maturity before harvest. Champlin and Goulden (1) conclude that while the quality of wheat and flour is improved when the wheat is allowed to become dead ripe, farmers are not warranted in exposing the crop to this extent, and should begin to harvest at an earlier stage.

It would appear, therefore, that wheat which is maturing normally, from the standpoint of maximum yield and quality of grain, and as a guard against losses from shattering storms and insect pests, should best be harvested when the grain is in the very late dough stage and the kernel sufficiently hard that a reasonable amount of pressure by the thumb nail must be exerted to make a dent in the grain.

THE EFFECT OF RUST ON MATURITY

Assuming that wheat which is maturing normally should be harvested when the kernels are in a semi-hard stage, do the conditions change when the natural filling processes are interfered with, as, for example, the interference brought on by an epidemic of stem rust?

The belief popularly exists that grain attacked by stem rust should be harvested when the plant is still immature. The assumption is that grain thus harvested is protected against the total injurious effects from stem rust, and that if harvested it will fill out better in the sheaf, producing a grain of higher quality than it would if left to reach the average degree of maturity.

With the recent and increasing frequency of stem rust in the spring wheat regions, the basis and soundness of this popular belief merits investigation. In spite of the seeming importance of the

question and its direct bearing on our crop yields, the basis for this belief has apparently not been considered by many investigators, and very little literature seems to be available which deals with this subject in a specific way.

A number of analyses are available of rusted and rust-free wheat, both in the grain and in the straw. Shutt (7) concludes that "Rust arrests the development and induces premature ripening, which means a straw in which still remains the elaborated food, and a grain immature, small, rich in protein, and deficient in starch." Snyder (8) found that wheat from rusted plants contained a higher percentage of protein, fiber and ash than fully matured, non-rusted wheat grown under the same conditions. Headden (3) came to a different conclusion regarding the proportions of starch in shrunken and non-shrunken wheat, and his observations indicate that there was very little difference between the two. Ince (4) found that rusty wheat straw was richer in protein, ash, and fat, but less rich in carbohydrate materials than the non-rusted wheat straw. Ellis (2) studying the stage of maturity of cutting wheat when effected with black stem rust, found that "grain should not be cut at a stage before it would be harvested in the ordinary course of events, if rust were absent, and that the maximum wheat is secured when grain cannot be crushed when pressed between the thumb and fore-finger." His more complete observations indicate premature cutting resulted in: brighter color and lustre, many shrunken grains of a brick red color, considerable number of green and immature kernels, shrunken berries and decreased yields.

RESULTS FROM EARLY AND LATER HARVEST OF RUSTY WHEAT

To determine the effect of early harvesting of rusty wheat, a field of Marquis in 1922 was staked into small areas and individual plats hand harvested.

Seven such equalized areas, each three meters square, were harvested at an early stage, or about when the kernels were in the dough stage. These will hereafter be referred to as "A" plats. At this period the heads were beginning to change slightly in color and in general would be considered likely to become normally ripe about four days later. Harvest of these early plats was made on July 31. Observations had previously been made as to the stage of development of the kernel, estimate of stem rust, etc. The average estimate of stem-rust infection on July 31 was 75 to 80 percent. These seven areas were selected in the field so as to permit the harvest of an equal

area immediately adjoining when the crop should become normally mature.

The second, or normal, harvest, hereafter referred to as "B" plats, was made on August 5. But for the rush of other harvest it would have been made on August 4, four days later than the early harvested plats.

The sheaves from both series of plats were shocked out-doors in the open, but covered to protect against birds and possible hail damage. During the winter months detailed data were recorded on these harvested crops. These comparative data include the number of heads, the yield and grade of grain, and other factors essential to measure the quantity and quality of the crop.

Threshing of the sheaves from these plats was made with a small nursery thresher. The shrunken condition of all the grain made threshing from both the early and late harvested plats difficult. The observations which it was possible to make did not indicate any increased difficulty in threshing the wheat from the early harvested plats.

Agronomic Data

As shown by the agronomic data, summarized in Table 1, the total number of heads harvested amounted to about 17,000, or as an average of 7 areas for each harvest date, nearly 2,500 heads per plat.

TABLE 1.—*Average number of heads, their grain, yield per acre, test weight, and weight per M kernels from rusted wheat harested early and harvested at the normal stage of maturity*

(The results are the average of 7 areas for each harvest)

Factors measured	Early harvest	Normal harvest	Difference favor of normal harvest
Number heads threshed[1]	2422	2458	
Grain per head (grams)	.3627±.005	.4041±.008	+.0414
Yield per acre (bushels)[1 2]	14.03±.33	15.53±.60	+1.50
Test weight (pounds)	51.03±.28	52.14±.34	+1.11
Wt. per 1000 kernels (grams)	18.29±.26	18.40±.34	+0.11

[1]Average of six areas.
[2]Based on equal number of heads.

The average grain produced per head for those plats harvested early amounted to .3627±.0050 grams; for those harvested later, or at the usual stage of maturity, .4041±.0084 grams. The difference in yield of grain per head amounted to .0414 grams, or a gain of nearly 12 percent in favor of the normally harvested plats. Each of these seven areas harvested at the later date returned more grain per head than its corresponding plat from the early harvest.

In grain per acre, calculated on the basis of an equal number of heads threshed, the "A" plats, or those harvested early, yielded

14.03±.33 bushels, while the "B" plats, harvested later, yielded 15.53±.60 bushels, an average gain in yield of 1.5 bushels, amounting to 10.7 percent.

A higher quality of wheat was produced on the "B" plats, as determined by the average test weight of the "uncleaned" grain. The test weight of the grain from the early harvested plats averaged 51.03 pounds per bushel and of that from the later harvested plats, 52.14 pounds. The wheat from the "A" plats gained more in test weight upon cleaning in preparation for milling than did that from the "B" plats, and after cleaning gave an average test weight of 53.64 pounds as against 54.07 for the "B" plats. Comparing the average weight per thousand kernels for the two stages of cutting, the difference is in favor of the plats cut at the normal stage of maturity. This would be expected from the weight of the grain per head, and the test weights recorded. The difference, however, is not significant, and an apparent inconsistency throughout these observations seems at this time hard to explain. Ellis (2) in 1919 at the Manitoba Agricultural College found that rusty wheat cut in the firm stage weighed 3 pounds more per bushel than when cut in the late milk stage.

According to the official grade for the different samples of wheat, six of the seven early harvested wheats graded No. 5 Dark Northern Spring, and one lot graded as sample grade. Of the wheats from the "B" plats, four graded No. 5 Dark Southern Spring and three graded No. 4 Dark Northern Spring, indicating a distinct advantage for the later harvested plats. All samples were recorded as 99 percent dark, hard vitreous, with no dockage.. Comparing the color of the samples of wheat, all were generally good. "B" samples, however were slightly better than "A" samples.

Milling and Baking Tests

The milling and baking tests on the samples were made in cooperation with the Department of Cereal Chemistry. The wheats from the seven "A" and seven "B" plats were milled and baked separately. The amount of grain did not permit more than one baking of each plat and the results presented herewith are the average of the seven plats from each of the early and normally harvested areas.

The seven early harvested plats gave 67.69 percent flour, slightly exceeding the later harvested areas, which averaged 67.22 percent. The slightly shrunken condition of the grain from the early harvested plats probably does not measure their true milling content. It is obvious that the more shrunken the kernel the more difficult it is to

secure a complete milling, and at the same time not include in the flour some of the bran and shorts. The color of the bread from the "A" plats suggests that perhaps the "A" plats were over-milled.

Flour from the "B" plats absorbed slightly more moisture than the "A" plats. In protein, based on an equal moisture content, (13.5 percent) there was very little difference between the early and the later harvested plats. The early harvested areas contained on the average a slightly higher protein content, which is in accord with other investigations. This difference, however, was not significant.

TABLE 2.—*Average results from milling and baking tests, and some chemical determinations of rusted wheat harvested early and harvested at the normal stage of maturity*

The results are the average of 7 areas or each harvest

Factors Measured	Early harvest	Normal harvest	Difference favor of normal harvest
Per cent flour	67.69±.23	67.22±.46	—0.47
Water absorbed (percent)	54.76±.03	55.04±.05	+0.28
Volume of loaf (cc.)	2216±15	2266±18	+50.0
Color of loaf (percent)	89.3	92.1	+2.8
Texture of loaf (percent)	91.0	93.0	+2.0
Protein (percent)[1]	10.69	10.54	—0.13
Ash (percent)[1]	0.501	0.468	—0.33

[1]Based on 13.50 percent moisture content.

In strength of flour, as measured by volume of loaf in the baked bread, the flour from the "A" plats showed an average loaf volume of 2216±14.96 cc. as compared to 2266±18.10 cc. for that from the "B" plats, an average difference of 50 cc. This difference, while not a significant one, is of greater value when considered with the other numerous factors wherein the later harvested plats have proved superior to those harvested at the earlier date.

Each of the flours from the seven "B" plats produced bread of a higher color score than that from its corresponding "A" plat. That from the seven "A" plats averaged in color score 89 as compared to 92 for that from the "B" plats. As suggested previously, this difference in color may be attributed in part to over-milling in the "A" samples, due to the more shrunken condition of the kernels brought about by premature harvesting.

The wheat from the later harvested plats made flour that produced a bread of better texture. The flour from six out of seven of the "B" plats graded higher in this respect than the corresponding "A" plats, the average texture score being 93 as compared to 91 for those harvested at the earlier date.

SUMMARY

Wheat maturing normally is ready for harvest when in the semi-hard condition. Too early harvest lessens the yield and quality of wheat produced. Gluten content and strength of gluten increase up to plant maturity, and color of flour is better from wheat allowed to mature fully.

Over-ripeness reduces the yields through shattering, excessive drying, and needlessly exposes the crop to insect pests, hail, and other crop destroying agencies.

Observations made in 1922, indicate that the wheat plant maturing under rust infections, having its natural maturing-processes interfered with, continues to transport into the wheat grain those materials that make up a desirable kernel. Too early harvesting of the rusted wheat prematurely shuts off the transportation process, reduces the possible yield, and tends to lessen the grade and the quality produced.

The existing idea in favor of the earlier harvest of rusted wheat is not based on facts. Justification of the practice must primarily be to protect the crop against hail, storm, and insect damage. The proper stage for harvest of rusted wheat would still appear to be the stage for a normal harvest, or when the grain is sufficiently firm so that a reasonable amount of pressure by the thumb-nail must be exerted to make a dent in the kernel.

LITERATURE CITED

1. CHAMPLIN, MANLEY, and Goulden, C. H. Milling quality of Saskatchewan wheat. Can. Soc. Tech. Agr. Tech. Bul. 1. 1922.
2. ELLIS, J. H. The stage of maturity of cutting wheat when affected with black stem rust. *In* Agri. Gaz., Can. Nov. 1919. p. 971.
3. HEADDEN, W. P. A study of Colorado wheat. Col. Agr. Exp. Sta. Bul. 219. 1916.
4. INCE, J. W. 22nd. Ann. Rpt. N. Dak. Agr. Exp. Sta. Pt. II, p. 120. 1911.
5. McDOWELL, R. H. Wheat-cutting at different dates. Nev. Agr. Exp. Sta. Bul. 30. 1895.
6. SAUNDERS, CHAS. E. The effect of premature harvesting on the wheat kernel. *In* Proceedings of the Edmonton Meeting, West. Can. Soc. Agron. 1:97. 1921.
7. SHUTT, FRANK T. Abs. in Exp. Sta. Rec. 16:585. 1904.
8. SNYDER, HARRY. Rusted wheat. Minn. Agr. Exp. Sta Bul. 90, p. 228. 1905.
9. STOCKHAM, W. L. Some factors related to the quality of wheat and strength of flour. N. Dak. Agr. Exp. Sta. Bul. 139. 1920.
10. THATCHER, R. W. The chemical composition of wheat. Wash. Agr. Exp. Sta. Bul. 111. 1913.

A SUGGESTED SYSTEM FOR HARVESTING HAY IN A CHOPPED CONDITION[1]

John P. Conrad[2]

The practice of chopping hay before feeding has been carried on by farmers more or less haphazardly since ensilage cutters and shredders have been available for that work. It has been useful usually when chopping has offered the best way of preparing hay otherwise refused by stock, or when it has been desired to facilitate measuring and mixing with other parts of the ration. (7)[3] Usually hay which has borne the costs of harvesting and stacking is pitched by hand into the ensilage cutter. In order that the latter may discharge directly into the hay mow or other place of storage, it has been found necessary in many cases to haul the hay from the temporary stack to the cutter; thereby increasing the number of times it is handled. With each handling (of legume hays, at least) more leaves, the most valuable part of the hay, are lost, unless unusual care is used. The cost of producing chopped hay by these methods is unnecessarily high.

In spite of the extra cost of producing chopped hay, the system has advantages. According to figures furnished by Tavernetti (15) chopped alfalfa hay occupies about 160 to 165 cubic feet to the ton as compared to an average of 150 cubic feet per ton as given by Freeman (5) for baled alfalfa hay and a range of 422 to 512 cubic feet to the ton as given by Stewart (14) for loose alfalfa. Hence, upon the farm chopped hay offers the advantage of reducing the space required for storage to about one-third of that required by hay in a loose condition.

The actual work of storing hay in the barn, where hay is run thru the ensilage cutter, is materially reduced from that required by loose hay. Blowing the material in replaces the complications of the tangling of tackle, the signaling of men, and the backing of horses. For this system, complex, cumbersome and expensive in human labor as it is now, is substituted a system, simple, effective and economical of labor in getting hay into the barn—the ensilage cutter.

Experiments reported by Cuming (4), Sanborn (13), Henry and Morrison (7), and Hickman and Rinehart (8, 9) seem to show that

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[2]Associate in Agronomy.

[3]Reference by number is to "Literature Cited." p. 51.

chopped hay is more effective in feeding livestock, pound for pound, than whole hay, tho neutral or negative results have been reported by Carlyle and Morton ([illegible]), Lindsey (10) and Morton (12). As suggested by Morton (12) and Henry and Morrison (7) chopping is probably most effective when the hay is coarse or stemmy or when a considerable portion of it is refused by the consuming animals.

To take advantage of the opportunities of lower cost for storage, lower cost of storing hay, and a possible greater feed economy in the use of chopped hay, a system of handling the hay to the cutter which would be cheaper and more efficient must be used. In an article by the writer (2) a system was suggested for harvested silage and soilage crops by the use of a "combined reaper ensilage cutter." The reaper part of such a machine could be removed and enough of a hay loader or other hay elevating device substituted to raise hay from the ground to the feeding apron of the machine. By going down a windrow made by a side delivery rake, the hay would be elevated into the machine, cut, and blown into the carrier bin. The top of the bin would require a canvas covering extending up to the end of the deflector to prevent the light material from being blown away. As soon as a "load" was secured the machine would go to the barn and blow the chopped material into the mow. Larger organizations might be served by delivering the chopped hay directly from the cutter into a wagon equipped with suitable bed driven alongside.

A few additional advantages of such a system suggest themselves:

1. The labor of harvesting hay and especially of putting it into the mow would be reduced to less than that of any system in general use at the present time (11). Only by trial can it be found whether the increased overhead charges of this system would more than offset the reduction in labor costs.

2. If silage and soilage crops were grown in addition, the fixed charges of this machinery would be divided among these three kinds of service. The systems of harvesting forage crops in these different forms have been built up on the basis of machines and processes or parts of machines and processes now in general use. It is possible and highly probable that some new mechanical device may be worked out which would be equally well or better adapted to each kind of work without the necessity of changing parts when the work is changed.

3. By turning the deflector of the machine as equipped for harvesting silage and soilage crops, so as to discharge onto the ground, corn and grain sorghum stalks left in the field after the ears and heads had

been harvested could be cut up so that tillage could go on without the implements clogging because of the long uncut stalks.

4. The number of men required at the "peak" of hay harvest would be reduced, as "machine labor" would replace "man labor."

5. A higher proportion of the leaves of legumes hays would be saved in the final chopped product than is saved by methods now generally used. The ensilage cutter would reduce all of the material to a size not much larger than the size of leaves. To handle any of the material, machines and wagonbeds would need to be made tight enough to hold in the leaves along with the stems. By the use of the system as outlined above the number of times the hay is handled before being chopped would be materially reduced with a resultant saving of leaves. Headdon (5) has found a mechanical loss of twenty per cent of the crop when hay is harvested under favorable weather conditions. Nearly all of this loss may be considered to be the leaves. More nutritious hay will result from preventing any part of this loss.

Attention should be called to the possible disadvantages of this system of hay harvest:

1. There might be danger of spontaneous combustion when the hay is put away somewhat damp. There seems to be no instructions to farmers, however, which stress the greater danger of baled hay burning over that of loose hay for the same percentage of moisture. Chopped hay having approximately the same volume weight as baled hay would seem to be equally safe.

2. Chopped hay might suffer on the market because of lack of means and equipment for handling it easily.

This system by applying the principles of the combined harvester to the harvesting of hay has been suggested primarily for hay intended for storage in barns. Greater weight per volume and greater ease in loading and in unloading into the barn together with a saving of a greater percentage of the leaves—all tend toward a cheaper cost of hay with its attendant cheaper cost of livestock production where stored hay is an important item in the cost of production. A study of the advantages of the blower stacker as described by Cumings (3) seem to offer the possibilities for use of this suggested system with appropriate devices, for outside stacks as well.

LITERATURE CITED

1. Carlyle, W. L., and Morton, G. E. Ration experiments with lambs. Colo. Agr. Col. Exp. Sta. Bul. 151. 1910.
2. Conrad, John P. A suggested System of Harvesting silage and soilage crops. *In* Jour. Am. Soc. Agron. Vol. 15:433–438. 1923.

3. CUMINGS, G. A. Methods of handling hay in Colorado. Colo. Agr. Col. Exp. Sta. Bul. 281. 1923.
4. CUMMING, M. Experiments with fattening steers. *In* Exp. Sta. Rec. 15:1101. (Abstracted from Ontario Agr. Col. and Exp. Farm Rpt. 1903. pp. 84–87.)
5. FREEMAN, GEO. F. Alfalfa in the Southwest. Ariz. Agr. Exp. Sta. Bul. 73. 1914.
6. HEADDON, W. P. Alfalfa. Colo. Agr. Col. Exp. Sta. Bul. 110. 1906.
7. HENRY, W. A. and MORRISON, F. B. Feeds and feeding. Madison, Wisc. 1917.
8. HICKMAN, C. W. and RINEHART, E. F. Steer feeding experiments. Ida. Agr. Exp. Sta. Circ. 28. 1922.
9. HICKMAN, C. W., and RINEHART, E. F. Lamb feeding experiments. Ida. Agr. Exp. Sta. Circ. 29. 1922.
10. LINDSEY, JOSEPH B. The nutrition of horses. Hatch Exp. Sta. (Mass.) Bul. 99, Part II. 1904.
11. MCCLURE, H. B. A study of haymaking crews and labor costs. U. S. Dept. Agr. Bul. 578. 1918.
12. MORTON, G. E. Feeding experiments with lambs. Colo. Agr. Col. Exp. Sta. Bul. 187. 1913.
13. SANBORN, J. W. Feeding horses hay and grain mixed. Utah Agr. Exp. Sta. Bul. 13. 1892.
14. STEWART, GEO. Alfalfa production under irrigation. Utah Agr. Exp. Sta. Circ. 45. 1921.
15. TAVERNETTI, THOS. Private correspondence to the writer. 1923.

INFLUENCE OF SOIL TYPE ON THE YIELD AND QUALITY OF PECANS[1]

J. J. SKINNER[2]

Variations in yield, size, and quality of pecans grown on different soil types have been noted in connection with investigations with the nut crop in the pecan belt of the South. The data secured showing these variations, which seem to be due to the soil on which they are grown, while not final, are here given as a progress report.

The pecan is native in the rich overflow lands of the Mississippi valley and the dark deep soils of the southwestern states, but the modern pecan industry has been developed on the loams and sandy loams of the upper coastal plain soils of Georgia, Florida, and Alabama. The success of orchards has depended to a great extent on the soil selected and its cultural management. While no specific soil type or class can be designated as having the best qualities for pecan culture, it is recognized that the soil type is an important factor,

[1]Contribution from Office of Soil Fertility Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C. Received for publication December 2, 1923.

[2]Biochemist.

and that there are differences in the yield and quality of the crop produced on the different soils. The loams and sandy loams of the Greenville, Orangeburg, Norfolk, and Ruston soils have been utilized extensively for pecan growing in these states. They are the prevailing types of this belt and the experiments conducted are on these soils.

FIRST EXPERIMENT

In a block of trees comprising 23 acres, near Albany, Georgia, the major part of which was utilized for fertilizer investigations, a section of the orchard was left unfertilized to serve as checks. The main portion of this orchard is on the Orangeburg sandy loam, but it contains small areas of the Greenville sandy loam, Norfolk sandy loam, and Ruston sandy loam. The orchard is composed of Stuart, Schley, and Alley trees and some of each of these varieties occur on each of the four soil types. The section of the orchard where this soil variation occurs was not included in the fertilizer experiment but records were kept of the yield, growth, etc., of these trees and an analysis of the nuts was made. It is on the results from these unfertilized areas that the data here given are based. The trees were set in 1910 and have been under the same cultural system and general farm management since the orchard was started. Yield and growth records of the trees have been kept since 1918. In 1922, nuts from each of the trees growing on the different soil types were examined in the laboratory to determine their size and filling quality and analyzed to determine the quality of the meat. The character of the kernel was studied by determining its per cent of protein and oil.

In Table 1–A, B, C, the data concerning Schley pecans grown on Orangeburg sandy loam and Norfolk sandy loam; Alleys on Greenville and Norfolk soil; and Stuarts on Orangeburg and Ruston soils are presented. Comparisons should be made in each case between a single variety grown on two soil types as presented in the Table. The records given are averages of six trees in each case.

In Table 1–A, the size and quality of Schley pecans grown on Orangeburg and Norfolk sandy loams are given. The yield from these trees has in the five years of observation, from the 7th to the 12th year of their growth, been greater by 16 percent on the Orangeburg soil than on the Norfolk soil. The size of the nuts is slightly larger as shown by their diameter and length, as well as weight. The percent of meat, which could be taken as the filling quality, is approximately the same for both soil types. The nuts from the Orangeburg soil contain 63.7 percent meat and those from the Norfolk soil 63.0 percent. The oil content of the kernel was slightly less

TABLE 1.—*Influence of soil on the size and quality of pecans at Putney, Georgia.*
A—Schley Pecans on Orangeburg and Norfolk sandy loam.

	Orangeburg sandy loam	Norfolk sandy loam
Number of nuts per pound	66	70
Diameter of nut in 64th inch	56	54
Length of nut in 64th inch	108	105
Meat in nut, percent	63.7	63.0
Oil in kernel, percent	77.0	78.1
Protein (Nx6.4) in kernel, percent	9.6	8.1

B—Alley Pecans on Greenville and Norfolk sandy loam.

	Greenville sandy loam	Norfolk sandy loam
Number of nuts per pound	71	80
Diameter of nut in 64th inch	56	54
Length of nut in 64th inch	87	85

C—Stuart Pecans on Orangeburg and Ruston sandy loam.

	Orangeburg sandy loam	Ruston sandy loam
Number of nuts per pound	60	60
Diameter of nuts in 64th inch	57	57
Length of nuts in 64th inch	91	87
Meat in nut, percent	49.0	49.7
Oil in kernel, percent	73.7	72.6
Protein in kernel, percent	12.6	12.8

and the protein content slightly larger in the nuts grown on the Orangeburg soil, than on the Norfolk soil.

In Table 1–B, a comparison is made of Alley pecans grown on Greenville sandy loam and Norfolk sandy loam. The size of the nuts only is given, no analysis of the kernel having been made. The yield on these trees during the five years has been 29 percent greater on the Greenville soil than on the Norfolk soil. The data show that there was a larger yield and larger and better filled nuts on the Greenville soil than on the Norfolk soil.

In Table 1–C, the data are given for Stuart pecans on Orangeburg and Ruston soil. The yield was 28 percent larger from the trees on the Orangeburg sandy loam. There is no significant difference, however, in the size of the nuts or the quality of the kernel produced on the two soils.

From the yield secured and analysis of the nuts grown on the different soils in this orchard it seems apparent that the soil has had some slight influence on the crop. The yield and quality of the nuts grown on the Greenville and Orangeburg sandy loams are somewhat superior to those grown on the Norfolk sandy loam or Ruston sandy loam. These four soils occur extensively in the coastal plains of the South Atlantic and Gulf Coast states and are among the principal soil types in this section of the pecan belt. The Greenville and

Orangeburg soils are closely related geologically and are good agricultural soils. The Norfolk soil also occurs with the former types and is closely related to the Ruston soil. The Greenville type has reddish brown to red surface soil and bright red sub-soil. The Orangeburg type has gray to brown surface soil underlain by bright red sub-soil. The Norfolk type has a gray surface soil and yellow sub-soil while the Ruston has a brownish gray surface soil with a pale yellow to reddish yellow sub-soil.

Each of these types when well grained and in a high state of productivity is suited to the growing and production of pecans. Any variation in the growth of the trees or quality of the nuts produced on the different soil types should be of interest and would seem significant.

SECOND EXPERIMENT

A similar experiment to the one just described was made at Cairo, Georgia, on a 15-acre orchard. Three soil types; Norfolk sandy loam, Greenville sandy loam and Susquehanna sandy loam are present in the orchard, which was originally of the Frotscher variety planted in 1904, but alternate trees were top worked to Money Maker in 1918. Previous to 1918 this 15-acre tract was badly rosetted and in a run-down condition yielding few or no nuts. Since that date it has been greatly improved by the growing and turning under of cover crops. A fair crop of nuts was produced in 1919 on the Frotscher trees and good crops on both Frotscher and Money Maker in 1921 and 1922. The 1920 crop was destroyed by insects.

Of the soil types occurring in this orchard the trees are better on the Norfolk and Greenville soils than on the Susquehanna.

Nuts were secured in 1922 frcm three trees growing on each of the three soils types, which had received no ccmmercial fertilizer, that is, those trees which had served as checks in a fertilizer experiment. The results of analysis of these nuts together with the yields and the chemical data of the soil are given in Tables 2–A & B.

In Table 2–A, the data are given for the Frotscher nuts grown on Greenville, Norfolk, and Susquehanna soils. The yield from the trees on the Greenville and Norfolk soils is respectively 27 and 23 percent greater than from those grown on the Susquehanna soil and the nuts, as determined by measurement and the number per pound, are larger. The percent of meat of the whole nut was 54.2 for the Greenville, 53.5 for the Norfolk, and 50.5 for the Susquehanna.

The percent of oil in the kernel did not vary greatly, but was slightly less in the nuts from the Susquehanna soil. The nuts from the

TABLE 2.—*Influence of soil on the size and quality of Pecans at Cairo, Georgia.*

A—Frotscher pecans grown on Greenville, Norfolk, and Susquehanna sandy loam.

	Greenville sandy loam	Norfolk sandy loam	Susquehanna sandy loam
Number of nuts per pound	70	67	76
Diameter of nuts in 64th inch	59	58	57
Length of nuts in 64th inch	97	99	89
Meat in nut, percent	54.2	53.5	50.5
Oil in kernel, percent	68.5	67.3	66.5
Protein (Nx6.4) in kernel, percent	14.5	12.8	12.6

B—Money Maker pecans grown on Greenville, Norfolk, and Susquehanna sandy loam.

	Greenville sandy loam	Norfolk sandy loam	Susquehanna sandy loam
Number of nuts per pound	79	78	113
Diameter of nuts in 64th inch	54	54	53
Length of nuts in 64th inch	80	78	75
Meat in nut, percent	51.2	50.2	49.4
Oil in kernel, percent	71.8	75.0	69.5
Protein (Nx6.4) in kernel, percent	11.4	11.8	10.3
Carbon content of soil, percent	1.99	0.94	1.48
Nitrogen content of soil, percent	0.091	0.046	0.059
Hydrogen-ion concentration of soil (pH)	5.4	5.9	5.8

Greenville soil contained 68.5 percent oil, from the Norfolk soil, 67.3 percent, and from the Susquehanna 66.5 percent. The protein of the nut meat was also less in the nut from the Susquehanna soil; which was 12.6 percent against 14.5 percent for the Greenville and 12.8 percent for the Norfolk.

The data for the Money Maker variety are given in Table 2–B. It is apparent that the size and quality of the nut is not as good on the Susquehanna soil as on the Greenville and the Norfolk. The yield of the nuts was 49 percent greater for the Greenville and 43 percent greater for the Norfolk than for the Susquehanna soil. The percent of meat, oil, and protein was also less. With both varieties, the Susquehanna soil produced an inferior nut and a smaller yield than did the Greenville and Norfolk soils in this orchard.

The Greenville soil contained more organic matter and nitrogen and was slightly more acid than the Norfolk and Susquehanna soils.

THIRD EXPERIMENT

In 1922, pecans were secured from two orchards in Baldwin County near Robertsdale, Alabama; one of which was on the Orangeburg sandy loam and the other on the Greenville sandy loam. The orchards were situated in close proximity to each other, were owned and managed by the same party and the cultural system for both was the same. The trees were of the Schley variety and were set out in 1912. Both have grown well and have been successful. The

orchard on the Greenville sandy loam comprised 5 acres and that on the Orangeburg sandy loam, 15 acres.

Nuts secured from the 1922 harvest were analyzed and graded and the data given in Table 3.

TABLE 3.—*Influence of soil on the size and quality of Schley pecans grown on two soil types at Robertsdale, Alabama.*

	Greensville sandy loam	Orangeburg sandy loam
Number of nuts per pound	60	67
Average weight of nuts, grams	7.5	6.8
Diameter of nuts in 64th inch	54	52
Length of nuts in 64th inch	118	110
Meat in nut, percent	61.4	59.4
Oil in kernel, percent	78.5	78.2
Protein in kernel, (Nx6.4) percent	11.6	11.0
Sugar (invert) in kernels, percent	2.6	2.5
Carbon content of soil, percent	1.6	1.4
Nitrogen content of soil, percent	0.059	0.057
Hydrogen-ion exponent of soil (pH)	5.8	6.4

As may be seen from Table 3, the nuts grown on the Greenville soil are larger and heavier. A record of the yield was not secured, but the manager of the orchard stated that the yield from the Greenville orchard was 25 percent greater than from the Orangeburg in 1922, and that this orchard had produced larger yields in previous years. The laboratory data unquestionably show that the nuts from the Greenville soil were larger and better filled than the nuts from the Orangeburg soil. The oil, protein, and sugar content of the pecans from the two orchards were practically the same.

An analysis of the soils showed the Greenville to contain slightly more organic matter and nitrogen than the Orangeburg.

The Greenville soil was more acid than the Orangeburg, the former had a pH value of 5.8 and the latter of 6.4.

The tree growth in the two orchards is very good and will compare favorably with the general run of pecans of the same age on these soil types. There was no apparent difference in the trees on the two soil types. There was, however, a difference in the yield, size, and quality of the nut; which appears to be due to the soil differences.

SUMMARY

The data given in the foregoing tables are from orchards where the factors, except the soil, are similar. In each case presented, it appears fair to conclude that the differences in yield, size, and quality of the nuts are due to the soil.

Schley pecans produced better yields and a larger nut on Orangeburg sandy loam than on Norfolk sandy loam at Putney, Georgia. There was very little difference in the percentage of meat, oil and protein content of the meat, from the nuts grown on the two soils.

Alleys produced larger yields and a larger nut on Greenville sandy loam than on the Norfolk sandy loam at Putney, Georgia. Stuarts produced larger yields on Orangeburg sandy loam than on Ruston sandy loam at Putney, Georgia. The size, percentage of meat and protein content of the meat, were practically the same in the nuts grown on the two soils. The oil content of the kernel was slightly higher in the nut from the Orangeburg soil.

Frotschers produced larger yields on the Greenville sandy loam and Norfolk sandy loam than on the Susquehanna sandy loam at Cairo, Georgia. The nuts were larger, better filled, and contained a higher oil and protein content on the two former types than on the latter. There was practically no difference between the yield and quality of the nut grown on the Greenville and Norfolk soil, the slight difference which prevailed was in favor of the Greenville soil. Money Makers produced larger yields, larger and better filled nuts of a higher oil and protein content on the Greenville sandy loam and the Norfolk sandy loam than on the Susquehanna sandy loam at Cairo, Georgia. There was practically no difference in the nuts from the Norfolk and Greenville soil.

Schleys produced larger yields and larger and better filled nuts on Greenville sandy loam than on Orangeburg sandy loam at Robertsdale, Alabama. The oil, protein, and sugar content of the kernel were practically the same in the nuts, grown on the two soil types.

MINIATURE THRASHER AND SEPARATOR[1]

W. W. Mackie and A. H. Hoffman[2]

Agricultural experiment stations have long sought a satisfactory machine for thrashing and separating the single bundle harvests of the rod-row experimental plots, which would clean itself automatically without stopping between bundles. To meet this need a new machine has been designed and built by the Agricultural Engineering Division of the University of California. It did excellent work at the University Farm at Davis this season.

The machine was designed to have the following characteristics:

1. Thorough removal of the grain from the head.
2. Little or no injury to grain by cracking or scratching.
3. Removal of straw and chaff without loss of grain.

[1]Contribution from the Division of Agronomy and of Agricultural Engineering, University of California, Berkeley, Calif. Received for publication November 24, 1923.

[2]Assistant Professor of Agronomy and of Agricultural Engineering, respectively.

4. Perfect automatic cleaning out of all grain from the entire machine after each sheaf is run through.
5. Adequate capacity for large as well as small bundles.
6. Ease of adaptation for grains of different thrashing characteristics.
7. Ease of adjustment and accessibility for inspection and repair.
8. Simplicity.
9. Small size and portability.
10. Strength and durability, lacking in wooden machines.

DESCRIPTION OF THE THRASHER

The new machine has but one shaft. On it are the cylinder and the blast fan. The concave is the overhead type. Beneath the cylinder and fan is the grain drawer. The air blast passes down through the fan housing, into and across the grain drawer, thence upward through the descending grain and out, carrying the chaff and straw away through a discharge tube. There are no racks, riddles or screens of any kind.

The sheet metal feed table has its bottom sloping at about ten degrees toward the cylinder except at the throat where the slope is twenty degrees. The bottom of the throat ends in a comb-shaped portion, the teeth of which dovetail in between the rows of cylinder teeth and prevent unthrashed heads dropping directly to the grain drawer. A heavy sheet rubber curtain hangs across the throat. Its lower edge is one inch from the feed table surface.

The cylinder is of gray iron cast integral. It is 8 inches long, 10¾ inches outside diameter, and 9¼ inches inside diameter. The open bell end is closed by the steel disk to which the blades of the fan are attached. The cylinder is machined to true circles and carefully balanced both before and after insertion of the teeth.

The overhead type concave is of gray cast iron ¾ inch thick, 8 inches wide and 160 degrees of arc in length. (This length suffices to direct the thrashed grain safely past the chaff outlet.) Cap screws held in slots in the support bars hold the concave securely and enable ready adjustment of tooth clearance.

The teeth for cylinder and concave are hand forged from ⅜ inch round mild steel rod. The working surfaces are casehardened. The length projecting is 1¾ inches. They are given a ⅜ inch S. A. E. standard screw thread of slight oversize and fastened into holes, drilled and tapped in cylinder and concave, and secured by lock washers and locknuts. The full complement of teeth is 48 for the 6 rows on the cylinder and 21 plus 6 half-teeth in 3 rows on the concaves.

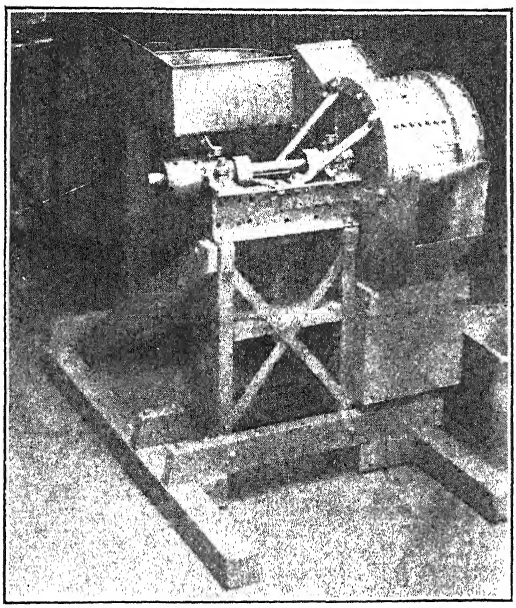

Fig. 1 Thrasher ready to go to the field. Feed table was level and grain drawer rectangular in the first machine.

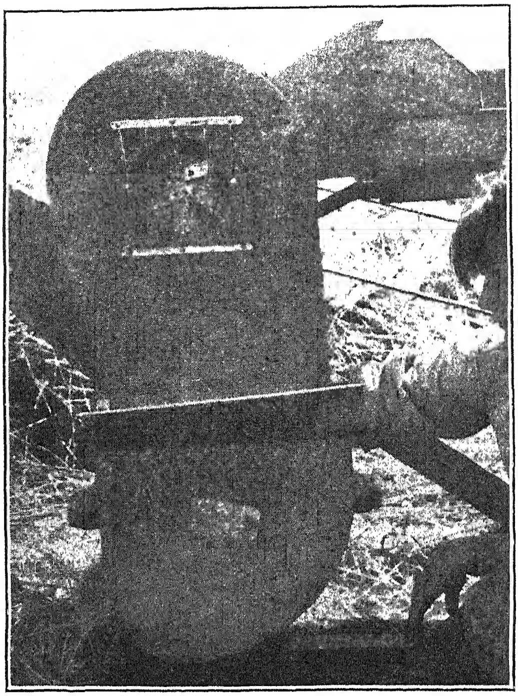

Fig. 2 Grain drawer in position for final cleaning. Grain is stirred by hand while fan blast blows straw joints out under deflector.

The half-teeth are carried by the housings. Their forward surfaces are sloped (making the section a right triangle with hypothenuse facing the oncoming grain) to avoid cracking.

The blast fan is of heavy sheet metal and is held to the open end of the cylinder casting by six $\frac{3}{8}$ inch capscrews, each of which passes through the supporting side of a fan blade. The fan diameter is $15\frac{3}{8}$ inches and the width $3\frac{3}{4}$ inches. Two slides regulate the size of the 6-inch diameter air inlet. A guard of coarse wires covers the inlet. Fan and cylinder are on the same $1\frac{3}{16}$ inch shaft but run in sheet metal housings which are separate down to the top of the grain drawer.

The grain drawer occupies the whole space under the cylinder and fan housings and fits closely to their lower edges. The curved bottom is designed to avoid dead air pockets.

A sheet metal deflector is hinged to the front of the machine directly above the grain drawer.

Places for grain to lodge and mix with a later batch, e. g. gaping joints, projecting bolt heads, nuts, screws, etc. in the interior of the housings, are carefully avoided in the construction. Good workmanship is essential.

The pulley used is lagged and is 4 inches long and 5 inches diameter. Too small a pulley is undesirable because of increased tendency for belt slippage and consequent non-uniformity of speed.

A 4 H. P. Cushman gasoline engine was used to drive the thrasher, though other makes of variable speed, throttle governed engines of 3-horsepower or larger size would be equally satisfactory.

OPERATION

The heads only are thrashed, the rest of the straw being drawn back and discarded.

For dry wheat, barley and oats of the Experiment Station at Davis, alternate teeth of the first row and all of the third row on the concave were removed. The clearance between teeth on cylinder and concave was set at $\frac{3}{16}$ of an inch. No change was found necessary.

The cylinder speeds used ranged from about 800 r. p. m. for the driest wheat to about 1300 for the barley when toughest. Since speed regulation could be obtained easily and in a moment, the speed was changed two or three times a day to get the best results. It was found possible to run at high enough speed to knock off the barley awns without blowing out any good grain.

After the last of a bundle is thrashed, any shelled-out grain on the feed table is brushed on in with a wisp of straw. Next, by pulling

one variety was distinctly higher yielding than the other. In every one of the nine years, Great Northern produced a higher yield than Big Four, and as an average of the entire period the difference was 7.4 bushels per acre. It is the attempt to harmonize these conflicting conclusions that has caused a distrust of the whole probable error concept in the minds of many.

Is there not a fundamental fallacy involved in the argument that Bessel's or Peter's formula is applicable to these and similar data? Has not the analogy between determinations made in the exact sciences and the measurement of field plot trials been drawn too closely? A physicist, for instance, may assume that under certain conditions light has a definite and fixed velocity which he desires to determine as accurately as possible. The deviations obtained in one hundred measurements of this value would be expected to approximate a normal curve of error about the true value. If there be calculated from this distribution the standard deviation and the probable error of the mean, an accurate measure of the reliability of the result is obtained, and it is easily possible to calculate the limits within which the chances are 1 to 1, 30 to 1, or 100 to 1, that the true value lies. Such a mean value, together with its probable error, may be compared with another mean value, together with its probable error measured under a different set of conditions, and conclusions drawn as to whether the two mean values are significantly different. Now in obtaining the mean yield of a given variety, or a given soil treatment, or a given rotation, there is no "correct" or "absolute" yield which may be approximated within the limits of experimental error. The final yields depend upon a complex series of environmental factors, many of which may be imperfectly controlled and many of which are wholly outside the realm of human control. This high variability cannot be emphasized too strongly, since apparently it is sometimes lost sight of in interpreting results. Some authors seem to accept the average of a series of plot yields as being of a definite value. Such an average is obtained from a set of variables and can only express the mean about which the variables fluctuate. In the series of yields given in Table 1, each year's results are separate identities depending in value upon the seasonal conditions, and upon the fertility of the individual plots where the experiments were conducted that year. It seems to be a mistake to assume that the differences from year to year are merely fluctuations about an absolute yield due to errors of random sampling.

What is the main point in such experimental trials is the comparison of yields of the two varieties and not the absolute yield of either

one. It is of interest to know both the mean gain of one over the other and the consistency of that gain. In other words, the problem deals with the pairing of each year's results in the order in which they occur. Bessel's and Peter's formulas pay no attention to this pairing. The degree of significance obtained by their methods would be the same irrespective of the order of the yields in the two columns; thus there would be obtained the same difference and probable error of the difference and, therefore, the same odds if the yields had been arranged in the arbitrary order shown in Table 2 without reference to the year in which they were obtained.

TABLE 2.—*Assumed rearrangement of yields from Table 1 paying no attention to pairing by years.*

	Yield per acre		
	Great Northern bu.		Big Four bu.
1915	78.9	1916	40.9
1913	73.9	1919	41.2
1912	71.0	1914	45.1
1918	63.0	1915	71.0
1914	48.9	1913	60.5
1919	48.4	1912	54.7
1920	48.1	1918	53.4
1917	47.9	1917	45.4
1916	43.5	1920	44.8

In this assumed order it appears that in the first instance Great Northern outyielded Big Four by 38.0 bushels per acre but in only four of the nine comparisons did the former outyield the latter at all. Although the degree of significance obtained by Bessel's or Peter's formula is the same for both tables, it is much easier to have confidence in the results indicated in Table 1, and to conclude from Table 1 that an actual inherent difference does exist between the yielding capacities of the two varieties under conditions existing at Ithaca, N. Y.

From the agronomist's point of view the comparison in Table 1 would have been no more convincing if all of the seasons concerned had happened to be similar, giving much more uniform yields within each variety. This uniformity in seasons, however, would have materially lowered the probable error of each mean, and consequently the probable error of the difference, so that the difference might conceivably become highly significant, even though the parallelism of the two varieties, the mean gain, and the consistency of the gain were no more pronounced. The crux of the whole situation seems to be that in using Bessel's or Peter's formula it is assumed that there is an actual definite mean yield for each variety or treatment; that deviations in yield due to seasonal or place effects are errors of random

sampling; and that the degree of parallelism between pairs of observations is of no moment in estimating the degree of significance of a difference.

In contrast to Bessel's and Peter's formulas there has been available for some time a method[3] which takes into consideration the parallelism of paired observations, and which gives weight to the amount and the consistency of the individual gains in estimating the significance of the mean difference. An anonymous author, signing himself "Student," published his first exposition of this method together with its mathematical proof in 1908, but unfortunately the advantages of this method thus far have been largely overlooked. In Table 3, the data presented in Table 1 are recalculated by this method.

TABLE 3—*The yields of two varieties of oats as shown in Table I. Probability of the difference calculated according to Student's method.*[4]

Year	Yields per acre Great Northern bu.	Big Four bu.	Gain of Great Northern over Big Four	D	D²
1912	71.0	54.7	16.3	−8.9	79.21
1913	73.9	60.5	13.4	−6.0	36.00
1914	48.9	45.1	3.8	3.6	12.96
1915	78.9	71.0	7.9	−.5	.25
1916	43.5	40.9	2.6	4.8	23.04
1917	47.9	45.4	2.5	4.9	24.01
1918	63.0	53.4	9.6	−2.2	4.84
1919	48.4	41.2	7.2	.2	.04
1920	48.1	44.8	3.3	4.1	16.81
		Mean	7.4		Σ 197.16
				$\sigma =$ 4.68	

$$Z = \frac{7.4}{4.68} = 1.58$$

P = .9989

Odds = 908 to 1

[4]It might be well in passing to point out that if one finds it more convenient to calculate σ (standard deviation) directly from the column headed "Gain of Great Northern over Big Four," it may be done without obtaining M-G and (M-G)². This is done as follows: Square the values in this column and sum. This gives 690. Divide this by the number of items (9) and this gives 76.6667. Square the mean difference 7.4 and subtract from 76.6667 which gives 21.9067. The square root of this is 4.68 or σ.

Deviations in this case are the differences between the annual gain of Great Northern and its mean gain. The values of P for corresponding values of Z may be found in Student's original articles or in Pearson's "Tables for Statisticians and Biometricians." The use of this method gives very high odds against the possibility that

[3]Student, Biometrika 6: 1-25, 1908. ibid. 11: 414-417, 1917.

such a difference between these varieties is due to chance, or in other words, if the same variety had been sown on the two plots each year, the odds are 908 to 1 against such a difference occurring. Unlike Bessel's formula, the results obtained from the use of Student's method are greatly influenced by the pairing of the comparisons, and this is what the investigator is interested in emphasizing.

Attention has thus far been confined to a series of comparisons extending over a period of years. Although the two varieties concerned were grown under comparable conditions each year, the seasonal conditions and the plots were so changed that the yields of each variety were subject to marked fluctuations from year to year. A somewhat similar problem is presented when the problem deals with yields for the same year or period of years, but from different locations. Here there is a high variability within a given treatment due largely to differences in productivity of the soil of the various localities, although differences in altitude, climate, etc., may have an appreciable effect if the several pairs of comparisons are far enough apart. The yields of corn reported from six outlying soil experiment fields in northern Illinois[5] comparing the effect of no treatment with the application of manure have been taken as an example of this class of data. The fields were all on the same soil type, subject to the same rotation and similar cultural conditions. The corresponding calculations of probability by Bessel's and Student's methods are given in Tables 4 and 5 respectively.

TABLE 4.—*The effect of manure on the yields of corn in different fields. Probability calculated according to Bessel's method.*

No. years averaged	Field	Yields per acre No treatment bu.	Manure bu.
4	Aledo	665.	79.1
4	Dixon	42.3	58.5
5	Joliet	32.0	39.5
4	Kewanee	59.0	68.2
4	La Moille	52.5	64.4
4	Mt. Morris	46.9	60.3
	Mean	49.9 ± 3.38	61.7 ± 3.60
	Difference	11.8 ± 4.94	

$$\frac{D}{\text{P.E.D.}} = \frac{11.8}{4.94} = 2.39 = \text{Odds } 8.3 \text{ to } 1$$

Due to the high variability in both the untreated and manured plots, the probable errors of the means in Table 4 are large, with the result that the use of Bessel's formula does not show a difference to be significant, altho it is manifestly so. Using Student's method in

[5]Circular 260, Illinois Agricultural Experiment Station.

TABLE 5.—*The effect of manure on the yields of corn in different fields as shown in Table 4. Probability calculated according to Student's method.*

No. years averaged	Field	Yields per acre: No treatment bu.	Manure bu.	Gain bu.
4	Aledo	66.5	79.1	12.6
4	Dixon	42.3	58.5	16.2
5	Joliet	32.0	39.5	7.5
4	Kewanee	59.0	68.2	9.2
4	La Moille	52.5	64.4	11.9
4	Mt. Morris	46.9	60.3	13.4
			Mean	11.8
			σ =	2.82

$$Z = \frac{11.8}{2.82} = 4.18$$

P = .9998
Odds = 4999 to 1

Table 5, the odds are very high that manure produces a significant increase over no treatment, as would be expected from a casual observation of the data. There is meant to be no implication that it is argued *a priori* that Student's method is the better method because it gives the greater odds. The advantage of Student's method is due rather to the fact that it recognizes the necessity of comparing the observations made under similar conditions and does not assume that there are absolute values in field trials from which all deviations are fluctuations due to errors of random sampling. The fact that conclusions reached with the aid of Student's method harmonize closely with the obvious facts of the case in the examples given, whereas those arrived at by means of Bessel's formula do not, leaves little argument in favor of Bessel's method for experiments similar to the ones cited. It also may serve to increase the confidence in Student's method of some who have not recognized the value of its application, where the deductions are not so obvious.

It is only a step from the example given in Tables 4 and 5, which includes plots from various parts of a state, to the consideration of a given experiment repeated on different portions of a non-uniform field. Where the different replications of an experiment fall on plots of different natural capacity (and they always do so to a greater or less degree), there are the same advantages from pairing the comparisons and using Student's method as in the case of the data in Table 5. It must be assumed, however, that the members of each pair are exactly comparable, and care must be exercised in planning an experiment to make this as nearly true as possible. It has been pointed out by various students of plot technique that increasing the number of replications does not in the majority of cases reduce

the probable error as calculated by Bessel's formula in accordance with mathematical expectancy, because it is impossible to obtain large areas as uniform as small areas. The use of Student's method does away with this argument against replication, since by using it the problem does not deal with the variability of each treatment as such, but only with the variability of the series of differences between the various pairs.

Student's method is, of course, not universally applicable and is not justified where the observations do not naturally fall into pairs as a result of the conditions of the experiment. Take, for example, two lots of steers being fed differently to determine the relative merits of two rations. Assuming that due care has been exercised to have all the animals in both lots as uniform as possible with respect to breed, age, and previous treatment, there is no reason why an individual of one lot should be compared with any one especial individual of the other lot. In this case the mean of each lot together with its probable error by Bessel's or Peter's formula is the best method of comparison. Similarly in the case of a number of freezing point depressions or osmotic pressure determinations, taken on the same material at the same time, Bessel's or Peter's formula would be the method to use. Where pot cultures in a greenhouse are replicated several times, there is no basis for pairing a pot of one treatment with a pot of another treatment unless the environmental conditions were more nearly alike for the pair than for the entire series.

Although Student's method may be used in calculating the significance of as few as two pairs of observations, extreme caution should be exercised in drawing conclusions from any experiment in which the number of replications is very small. In common with other measures of fluctuations in sampling, a strictly numerical interpretation of constants determined from small populations may give a false sense of security as to the reliability of the sample. As an example let us consider a hypothetical case involving a duplicated comparison of two varieties of wheat.

Variety A	Variety B	Gain	D	D^2
24.5	24.0	.5	0	0
27.0	26.5	.5	0	0
		Mean = .5	$\sigma = 0$	

$$Z = \frac{.5}{0}$$

P = 1.000

Odds are infinite.

Obviously the chances that variety A will always outyield variety B under these conditions do not amount to absolute certainty. As pointed out by Student in his original article, the probability obtained in using a very small number of instances is likely to be too high, and overconfidence in unexpectedly high odds under such conditions must be guarded against. Biometrical methods are such that they must be used with great care and the experimental results wisely and judiciously interpreted if the conclusions reached are to be of permanent value. Student's method is no exception to this rule, but when correctly used it is believed to be particularly applicable to the interpretation of many phases of agronomic work and to merit a wider recognition than it now enjoys.

SUMMARY

Too close an analogy should not be drawn between the determination of exact constants and the results of comparative agronomic experiments. Bessel's and Peter's formulas are not adapted to calculating the degree of significance of a difference between two varieties or two comparative treatments in experiments in which the variability within each variety or treatment is high because they extend through a series of years or because of place effect. For observations which naturally arrange themselves in pairs, Student's method is a better method with which to determine the probability of the difference, and deserves a larger application in the intrepretation of agronomic investigations.

A MODIFICATION OF STUDENT'S TABLE FOR USE IN INTERPRETING EXPERIMENTAL RESULTS[1]

H. H. LOVE[2]

Elsewhere in this JOURNAL[3] there has been presented some argument for the use of Student's method for interpreting the results of experimental work, particularly where the experiments have been so conducted as to admit of pairing. This method consists first in determining the difference between two experiments, say A and B. Then the mean difference or mean of these differences is obtained. The difference between each value and this mean is then obtained and from these values the standard deviation is calculated by the usual method.

[1]Paper No. 120, Department of Plant Breeding, Cornell University, Ithaca New York. Received for publication December 22, 1923.

[2]Professor.

[3]See preceding article.

Variety A	Variety B	(A-B) or D	D-M	$(D-M)^2$
29.3	20.4	8.9	− .3	.09
21.3	20.2	1.1	−8.1	65.61
30.7	20.1	10.6	1.4	1.96
30.2	23.4	6.8	−2.4	5.76
36.4	23.7	12.7	3.5	12.25
37.4	19.3	18.1	8.9	79.21
35.6	25.1	10.5	1.3	1.69
27.8	18.7	9.1	− .1	.01
24.7	17.4	7.3	−1.9	3.61
36.3	29.6	6.7	−2.5	6.25
	Sum	91.8		10|176.44

$$\text{Mean } \frac{91.8}{10} = 9.18 \qquad \sqrt{17.644} = 4.2$$

taken as 9.2

$$Z \frac{9.2}{4.2} = 2.2$$

For example, the following comparison between two varieties of wheat will illustrate the method:

When Z = 2.2 and n = 10 the odds from the table are found to be over 9999 : 1. This means that the odds are 9999 : 1, against a difference as great as this occurring due to chance alone. That is, the odds indicate a real difference in yielding power between these two varieties. If desirable the standard deviation may be calculated directly from column D, as given in the footnote in the preceding article.

For the values of Z obtained, Student has prepared a table showing the probability of a difference as great as that obtained being due to chance alone. From this table one can calculate the odds that such a difference is due to chance and express the final results as a ratio, such as 20 : 1.

Since this method is found very useful in our laboratory we have had occasion to calculate such odds very frequently. As this involved calculating odds for each determination or result, it seemed that it would be convenient to calculate the odds for the values in Student's tables so that one could refer directly to these values. This has been done by Miss Francis Feehan of this department, and, since it was felt that such a table might be useful to others, it is here presented.

In making these calculations the odds values for the probability value as expressed in Student's table have been calculated and in addition the table has been enlarged by determining the odds for the intermediate values of Z. For example, in the original table for the lower values for Z the difference taken is one-tenth. In this table as now calculated the intermediate values have also been calculated, such as .55, .65, and so on. This has been done by direct interpolation and is sufficient for all practical purposes.

TABLE 1—*The calculated odds for the Z values of Student's table for estimating the probability that the difference between a series of paired experiments is significant. (In addition to calculating the values for Z as given in Student's table the values for the intermediate classes have also been calculated.)*

Z	n=2	n=3	n=4	n=5	n=6	n=7	n=8	n=9	n=10
.1	1.14	1.22	1.29	1.35	1.40	1.46	1.50	1.55	1.59
.15	1.21	1.35	1.46	1.56	1.66	1.75	1.83	1.92	2.00
.2	1.29	1.49	1.66	1.82	1.97	2.12	2.26	2.41	2.55
.25	1.37	1.64	1.88	2.10	2.32	2.54	2.75	2.97	3.19
.3	1.46	1.81	2.13	2.44	2.76	3.08	3.41	3.75	4.11
.35	1.54	1.98	2.40	2.81	3.24	3.68	4.14	4.62	5.13
.4	1.64	2.18	2.72	3.27	3.85	4.48	5.15	5.88	6.67
.45	1.73	2.39	3.05	3.75	4.51	5.33	6.24	7.24	8.34
.5	1.84	2.62	3.44	4.35	5.36	6.50	7.80	9.26	10.9
.55	1.94	2.85	3.85	4.97	6.25	7.72	9.42	11.4	13.6
.6	2.05	3.12	4.33	5.75	7.42	9.42	11.8	14.6	18.0
.65	2.16	3.39	4.82	6.54	8.62	11.2	14.2	17.9	22.5
.7	2.27	3.69	5.41	7.55	10.2	13.6	17.8	23.1	29.8
.75	2.39	3.99	5.99	8.55	11.8	16.0	21.4	28.3	37.2
.8	2.51	4.33	6.70	9.82	14.0	19.5	26.8	36.5	49.3
.85	2.62	4.66	7.39	11.1	16.1	22.9	32.1	44 5	61.1
.9	2.75	5.04	8.22	12.7	18.9	27.7	40.0	57.1	81.0
.95	2.87	5.41	9.03	14.2	21.7	32.4	47.8	69.4	100.
1.0	3.00	5.83.	10.0	16.2	25.5	39.2	59.2	89.1	132.
1.05	3.12	6.24	11.0	18.2	29.1	45.7	70.4	108.	163.
1.1	3.26	6.69	12.1	20.6	34.0	54.9	87 5	138.	216.
1.15	3.39	7.13	13.2	22.9	38.7	63.5	103	166.	262.
1.2	3.52	7.63	14.5	25.9	44.9	75.9	127.	212.	344.
1.25	3.65	8.11	15.7	28.8	50.8	87.5	151.	255.	416.
1.3	3.79	8.64	17 2	32.3	58.5	104.	184.	322.	555.
1.35	3.92	9.16	18.6	35.8	66.1	119.	216.	384.	666.
1.4	4.07	9.74	20.3	40.0	75.9	142.	262.	475.	908.
1.45	4.20	10.3	21.9	44.0	85.2	163.	302.	555.	1110.
1.5	4.34	10.9	23.9	49.0	98.0	191.	369.	713.	1428.
1.55	4.48	11.5	25.7	53.9	109.	216.	434.	832.	1666.
1.6	4.62	12.2	27.7	60.0	124.	255.	525.	999.	1999.
1.65	4.76	12.8	29.8	65.7	138.	285.	587.	1110.	2499.
1.7	4.91	13.5	32.2	72.5	158.	332.	713.	1428.	3332.
1.75	5.05	14.2	34.5	79.0	174.	369.	832.	1666.	3332.
1.8	5.20	14.9	37.0	86.7	199.	434.	999.	1999.	4999.
1.85	5.34	15.6	39.5	94.2	216.	499.	1110.	2499.	4999.
1.9	5.49	16.4	42.5	103.	243.	587.	1249.	3332.	9999.
1.95	5.63	17.1	45.1	111.	269.	624.	1428.	3332.	
2.0	5.78	17.9	48.3	122.	302.	713.	1666.	4999.	
2.05	5.92	18.7	51.4	132.	332.	768.	1999.	4999.	
2.1	6.07	19.6	54.9	144.	369.	908.	2499.	4999.	
2.15	6.21	20.4	58.2	155.	399.	999.	2499.	4999.	
2.2	6.36	21.3	61.9	168.	454.	1249.	3332.	9999.	
2.25	6.51	22.1	65.2	181.	499.	1249.	3332.		
2.3	6.66	23.1	69.4	199.	555.	1428.	4999.		
2.35	6.81	24.0	73.1	212.	587.	1666.	4999.		
2.4	6.96	25.0	77.7	232.	666.	1999.	4999.		
2.45	7.10	25.9	81.6	249.	713.	1999.	4999.		
2.5	7.26	26.9	86.7	269.	768.	2499.	4999.		
2.55	7.40	27.9	91.6	285.	832.	2499.	4999.		
2.6	7.55	29.0	97.0	302.	908.	2499.	9999.		
2.65	7.70	30.1	102.	322.	999.	2499.			
2.7	7.86	31.2	108.	356.	1110.	3332.			
2.75	8.00	32.2	113.	369.	1110.	3332.			

TABLE 1 (*Continued*)

2.8	8.16	33.4	118.	399.	1249.	4999.
2.85	8.30	34.5	124.	416.	1249.	4999.
2.9	8.46	35.6	131.	454.	1428.	4999.
2.95	8.61	36.7	136.	475.	1428.	4999.
3.0	8.77	37.9	144.	525.	1666.	4999.
3.05	8.91	39.2	151.	555.	1666.	4999.
3.1	9.07	40.5	158.	587.	1999.	9999.
3.15	9.21	41.6	163.	587.	1999.	
3.2	9.37	42.9	171.	624.	2499.	
3.25	9.52	44.0	178.	666.	2499.	
3.3	9.67	45.5	188.	713.	2499.	
3.35	9.82	46.8	195.	768.	2499.	
3.4	9.98	48.3	203.	832.	3332.	
3.45	10.1	49.5	212.	832.	3332.	
3.5	10.3	51.1	221.	908.	3332.	
4.0	11.8	66.1	322.	1666.	4999.	
4.5	13.3	83.0	434.	2499.	4999.	
5.0	14.9	102.	624.	3332.	9999.	
5.5	16.5	122.	832.	4999.		
6.0	18.0	146.	999.	9999.		
6.5	19.6	171.	1249.			
7.0	21.1	199.	1666.			
7.5	22.7	226.	1999.			
8.0	24.3	255.	2499.			
8.5	25.8	293.	2499.			
9.0	27.4	322.	3332.			
9.5	28.9	369.	3332.			
10.0	30.5	399.	4999			
15.0	46.2	908.	9999.			
20.0	61.9	1666.				
25.0	77.7	2499.				
30.0	93.3	3332.				
35.0	109.	4999.				
40.0	124.	4999.				
45.0	140.	9999.				
50.0	153.					
60.0	188.					
70.0	221.					
80.0	249.					
90.0	285.					
100.0	311.					
120.0	369.					
140.0	434.					
150.0	475.					
160.0	499.					
180.0	555.					
200.0	624.					
250.0	768.					
300.0	908.					
350.0	1110.					
400.0	1249.					
450.0	1428.					
500.0	1666.					
600.0	1999.					
700.0	1999.					
1000.0	3332.					
1500.0	4999.					
2000.0	4999.					
3000.0	9999.					

Z	n=29	n=30
.1	2.33	2.37
.15	3.45	3.52
.2	5.69	5.90
.25	8.47	8.82
.3	15.2	16.1
.35	23.0	24.5
.4	45.3	49.3
.45	69.9	76.5
.5	151.	171.
.55	237.	269.
.6	555.	666.
.65	908.	1110.
.7	2499.	3332.
.75	3332.	4999.
.8	9999.	9999.

TABLE 1 (*Continued*)

Z	n=11	n=12	n=13	n=14	n=15	n=16	n=17	n=18	n=19
.1	1.64	1.68	1.72	1.76	1.80	1.84	1.88	1.92	1.96
.15	2.08	2.16	2.24	2.31	2.39	2.47	2.54	2.62	2.69
.2	2.70	2.84	2.99	3.14	3.29	3.44	3.60	3.75	3.91
.25	3.41	3.64	3.87	4.11	4.36	4.60	4.86	5.12	5.39
.3	4.48	4.86	5.27	5.69	6.13	6.59	7.08	7.59	8.12
.35	5.67	6.24	6.84	7.47	8.15	8.86	9.62	10.4	11.3
.4	7.53	8.45	9.47	10.6	11.8	13.1	14.5	16.0	17.7
.45	9.54	10.9	12.3	13.9	15.7	17.7	19.8	22.2	24.8
.5	12.8	14.9	17.3	20.1	23.3	26.8	30.8	35.4	40.7
.55	16.2	19.2	22.7	26.7	31.3	36.5	42.7	49.5	57.5
.6	22.0	26.8	32.4	39.3	47.3	56.8	68.4	81.6	98.0
.65	27.9	34.6	42.5	52.2	63.9	77.7	95.2	115.	140.
.7	38.1	48.5	61.5	77.7	99.0	124.	155.	195.	249.
.75	48.3	62.7	81.0	104.	134.	171.	216.	277.	356.
.8	66.1	88.3	118.	158.	207.	277.	356.	475.	624.
.85	83.7	114.	155.	207.	277.	369.	499.	666.	908.
.9	114.	160.	226.	311.	434.	587.	832.	1110.	1666.
.95	144.	207.	293.	416.	587.	832.	1110.	1666.	2499.
1.0	195.	293.	434.	624.	908.	1428.	1999.	3332.	4999.
1.05	243.	369.	555.	832.	1249.	1999.	2499.	4999.	4999.
1.1	332.	525.	832.	1249.	1999.	3332.	4999.	9999.	9999.
1.15	416.	666.	999.	1666.	2499.	3332.	4999.		
1.2	555.	908.	1428.	2499.	3332.	4999.	9999.		
1.25	713.	1110.	1666.	3332.	4999.	4999.			
1.3	999.	1666.	2499.	4999.	9999.	9999.			
1.35	1249.	1999.	3332.	4999.					
1.4	1666.	3332.	4999.	9999.					
1.45	1999.	3332.	4999.						
1.5	2499.	4999.	9999.						
1.55	2499.	4999.							
1.6	3332.	9999.							
1.65	3332.								
1.7	4999.								
1.75	4999.								
1.8	9999.								

Z	n=20	n=21	n=22	n=23	n=24	n=25	n=26	n=27	n=28
.1	2.00	2.03	2.07	2.11	2.15	2.18	2.22	2.26	2.29
.15	2.77	2.84	2.92	2.99	3.07	3.14	3.22	3.30	3.37
.2	4.08	4.24	4.41	4.58	4.76	4.94	5.12	5.31	5.50
.25	5.66	5.94	6.23	6.52	6.83	7.14	7.46	7.79	8.12
.3	8.68	9.27	9.89	10.5	11.2	11.9	12.7	13.5	14.3
.35	12.2	13.1	14.1	15.2	16.3	17.5	18.7	20.1	21.5
.4	19.5	21.5	23.7	26.0	28.6	31.4	34.3	37.8	41.2
.45	27.7	30.7	34.2	38.1	42.1	46.6	51.6	57.1	63.1
.5	46.4	53.1	60.7	69.4	79.0	89.9	102.	117.	132.
.55	66.6	77.1	89.1	103.	118.	136.	155.	181.	207.
.6	117.	140.	166.	199.	237.	277.	332.	399.	475.
65.	168.	203.	243.	302.	256.	434.	525.	624.	768.
.7	302.	384.	475.	624.	768.	999.	1249.	1666.	1999.
.75	434.	555.	713.	908.	1110.	1428.	1999.	2499.	3332.
.8	832.	1110.	1428.	1999.	2499.	3332.	4999.	9999.	9999.
.85	1110.	1428.	1999.	2499.	3332.	4999.	4999.		
.9	1999.	2499.	3332.	4999.	9999.	9999.	9999.		
.95	3332.	3332.	4999.	4999.					
1.0	9999.	9999.	9999.	9999.					

In order to save space in printing, the ratios of odds, that is 37:1, 40:1, and the like, have been shortened by omitting the last part of the expression. The values in the table should all be understood to be the first figures of the usual expression, thus for Z, .85 and n 10 the expression is read as odds of 61 : 1, against the occurrence of a difference as great as this between two sets of observations being due to chance alone. That is, if Z .85 represents the value found for the comparison made between two varieties, the odds are 61 : 1 against such a difference being found if both series of plats had been sown to the same variety.

BOOK REVIEWS

BOTANY

Principles and Problems.

By Edmund W. Sinnott, Professor of Botany, Connecticut Agricultural College. McGraw-Hill Agricultural and Biological Publications, edited by C. V. Piper. McGraw-Hill Book Co., Inc., New York. Pages 385; figs. 240. 1923.

This is the most recent addition to the McGraw-Hill series of Agricultural and Biological publications, of which Dr. C. V. Piper is the consulting editor. In its general mode of treatment of subject matter, it is somewhat more elementary in character than are other books of the series. In the opinion of the reviewer, however, the author has admirably accomplished his purpose to prepare a general text-book in elementary botany for college freshmen. The book is quite a departure from the older type of texts which over-emphasized taxonomic relationships, since it deals chiefly with the general phenomena of plant growth, and only in the latter chapters introduces the specific study of the separate subdivisions of the plant kingdom.

After introductory chapters dealing with the science of botany and the plant kingdom in general, successive chapters treat of the soil and its importance to plants; the root, the stem, the leaf, and their functions; metabolism; growth; influence of environment; reproduction; heredity and variation; and evolution. The remaining five chapters are devoted to the plant kingdom in general; the thallophyta; the bryophyta; the pteridophyta; and the spermatophyta.

Each chapter of the book concludes with numerous "questions for thought" and "reference problems," which are carefully prepared and well calculated to "stimulate within the student an attitude of interest of curiosity and of critical thought toward the multitude of problems which plants provide, and thus to provide him with a clearer insight into the ways in which plants are constructed and function, and a firmer command of botanical science in general, than can be given him merely through a series of lectures and recitations." (Quotation from Preface.)

The book is uniform with others of the series in printing and binding and is, therefore, excellent in mechanical make-up.

(R.W.T. and J. T. O'D.)

THE MICRO-ORGANIC POPULATION OF THE SOIL

By Sir E. John Russell, Director Rothamsted Experiment Station, Harpenden, England, and members of the biological staff of the Rothamsted Station. Rothamsted monographs on Agricultural Science, edited by Sir E. J. Russell. Longmans Green and Co., New York and London. 188 pp. 1923.

This monograph, besides an opening and closing chapter by the senior author, contains two chapters on bacteria by H. G. Thornton, two on protozoa by D. W. Cutler, one on algae by B. Muriel Briston, two on fungi by W. B. Brierley, and one on invertebrates other than protozoa by A. D. Imms. Altho the work is one of collaboration, it avoids the error of lack of coordination so common in works of this kind, undoubtedly due to the close association of the various authors and to the careful planning of the whole monograph by the Director of the Station. Thus the book has all the advantages of a collaboration, without the weaknesses so often associated with such an undertaking.

The book is a summary of the present knowledge concerning the groups of microorganisms above mentioned as inhabitants of the soil, dealing both with the types of the different organisms and with their activities. Soil bacteriology, as the subject is generally understood, is briefly treated without any attempt to summarize the entire past accumulation of knowledge; but as the various biological activities are discussed under the different groups of organisms, no one can read the book without getting a very good idea of the whole field. The section written by each author contains an historical review of the subject, but lays particular stress on recent Rothamsted work, often reporting results not previously published. Altho dealing so largely with Rothamsted work, the results of other workers are very judiciously handled. The authors are especially cautious in interpreting laboratory findings, avoiding the error of assuming that they represent natural conditions.

The book should be of value both to the investigator and to the teacher. The latter could hardly put it in the hands of elementary students; but for advanced students specializing in the microbiology of soil it should prove a very useful reference book and in some classes a valuable text book. (H. J. Conn.)

THE POTATO

Its Culture, Uses, History and Classification

By William Stuart. Philadelphia: J. B. Lippincott Co., IX 518 pp., Pls. 5, Figs. 267. 1923.

This book, coming as it does from the leading authority on the subject in America, will at once take its place as the standard reference work on the potato. Designed primarily for use as a college text book, the comprehensive scope and lucid treatment make the

volume indispensable to those engaged in potato investigations and of much practical value to those who grow potatoes for profit. The first section of the book deals with all phases of potato production in the United States, taking up separately the different sections of the country and discussing in detail the problems peculiar to each section. The harvesting, storing, and disposal of the crop receive detailed attention, while potato diseases and insect pests and their control are fully dealt with. The second section treats of the botany of the potato, the origin and early history of the plant, and potato breeding and selection. An important chapter in this section is the one dealing with methods of classifying and describing commercial varieties of potatoes, including the well-known system devised by the author and published first as United States Department of Agriculture Bulletin No. 176.

College extension workers and teachers in vocational schools and agricultural high schools will be especially interested in an outline presented in the Appendix for a student project in growing a field of potatoes for profit. Educational features to be found in carrying out such projects are listed, and methods of organizing potato exhibits explained. Much statistical information on potato varieties and on potato production in the United States and Canada is also included.

Altho the literature on the potato is already voluminous, this new contribution will be a welcome addition because it assembles in one place practically all that the student will need to know about potato growing in the United States, thus obviating the necessity of search in several places. Bibliographical citations at the end of each chapter will aid those who desire to go deeper into certain phases of the subject. (J. D. L.)

THE STORY OF THE MAIZE PLANT

By Paul Weatherwax. Chicago: The University of Chicago Press, XV+247 Pp., Pls. 2, Figs. 174. 1923. $1.85 postpaid.

Based chiefly on the author's studies of the botany of the maize plant, but drawing on other sources of information as well, this volume presents a concise and readable account of the present botanical knowledge of maize. The economic aspects of corn-growing are dealt with only lightly, the predominant theme being the botanical relationships and morphology of the corn plant. Altho the author disclaims any attempt at an exhaustive treatment of the subject, the agronomist will find the chief value of the work to lie in the assembling in one place of a large amount of reliable information about corn. The book is profusely illustrated, chiefly with original drawings by the author in an effort to correct errors which prevail in text books dealing with maize. An especially helpful feature is a bibliography of 172 titles, which the author says "are intended merely to direct the reader to more detailed treatments of the various topics, and to cite the sources of many points of unusual interest." The volume is a valuable addition to the literature on maize. (J. D. L.)

THE PRINCIPLES OF INSECT CONTROL

By Robert A. Wardle, Lecturer in Economic Zoology in the University of Manchester and Philip Buckle, Lecturer in Agricultural Zoology in the University of Durham. The University Press, Manchester, 1923. Pages 295. 1 Plate (Frontispiece) and 32 text figures.

This book gives in an exceptionally clear and concise way the approved practices relative to insect control and of the principles involved. It is divided into the following parts: (1) Biological control, considering host resistance, climatic restraints, disease, parasites, birds, etc.; (2) Chemical control; (3) Mechanical control; (4) Legislative control, with an appendix dealing with spraying and dusting machines.

The book is a ready reference work and index to the extensive literature summarized in the text, covering a wide range of scientific and technical journals. The discussion relative to the chemical nature of insecticides constitutes one of its most valuable features, dealing as it does with a large number of materials and covering both theoretical and practical aspects of the subject.

The authors have rendered a distinct service in preparing the book. It presents a number of features of particular interest to American workers in this field and occupies a useful place in the working library of economic entomologists generally. (P. J. Parrott.)

AGRONOMIC AFFAIRS

NOTES AND NEWS

The note in this JOURNAL of September, 1923, which stated that Dr. C. B. Hutchison had been appointed Director of the California Experiment Station was an error. Dr. C. M. Haring, who has been Director of the Station for several years under Dean Hunt, upon the latter's resignation, asked to have his title changed to Acting Director until the new Dean is appointed. This has, however, in no way changed his duties as director.

D. R. Hoagland, Associate Professor of Plant Nutrition at the University of California, has been granted a year's sabbatical leave of absence for foreign travel and study.

The Sewerage Commission of Milwaukee has placed at the disposal of the College of Agriculture of the University of Wisconsin the sum of $1,500 for the establishment of a fellowship to study the best methods of using activated sludge as a fertilizer. O. J. Noer has been appointed to the fellowship to work under the direction of Dr. Emil Truog.

Dr. G. F. Freeman, Chief of the Division of Plant Breeding at the Texas Experiment Station, has accepted an appointment as Director

of the newly created Technical Service in the Haitien Department of Agriculture, and began his work there on September 1.

Professor Chas. F. Shaw, of the Department of Soil Technology of the University of California has returned from an extended trip thru Australia, New Zealand, and Hawaii. He brought back numerous soil samples for further study.

Dan T. Gray, Dean of Agriculture and Director of the Alabama Agricultural Experiment Station, has resigned to become Dean of Agriculture and Director of the Experiment Station at the University of Arkansas, effective January 1, 1924.

Harry V. Harlan, Agronomist in Charge of Barley Investigations of the U. S. Department of Agriculture, who is spending a year abroad in a special search for primitive forms of barley and other cereals, is now in Abyssinia where he will follow the ripening of the barley crop to successively higher elevations. He has already covered northern Africa from Algeria to Egypt and as far south as the Sahara and has made extensive collections in parts of India. He expects to return to the United States on or about the end of February, 1924. All his cereal collections received by the Department to November, 1923, have been sown at the Sacaton Experiment Farm, Sacaton, Arizona, where winter varieties can be separted from those having spring habit without danger of losing either.

Fred D. Richey, Agronomist in Charge of Corn Investigations of the Office of Cereal Investigations, U. S. Department of Agriculture, and Dr. R. A. Emerson, Head of the Department of Plant Breeding of Cornell University, will leave for South America in January, 1924, under the auspices of the two institutions. Their mission is to obtain the largest possible collection of primitive corns from the high plateaus and mountain valleys of the south and central portions of the Andean mountain system. It is hoped that from these sources much material can be obtained which will have value in breeding corn for resistance to disease and unfavorable climatic conditions. They expect to return to the United States in June.

Franklin A. Coffman, at present Assistant Agronomist in charge of Cereal Investigations at the Akron Field Station, Akron, Colorado, will be transferred to Washington, D. C., at the end of December, 1923, to become assistant in oat investigations in the Office of Cereal Investigations.

Gus A. Wiebe, Junior Plant Breeder in cooperative cereal investigations at the Aberdeen (Idaho) Substation, arrived in Washington, D. C., on November 27 to prepare his annual report and continue study in the Graduate School of the Department of Agriculture.

Dr. E. C. Stakman, Plant Pathologist of the Minnesota Agricultural Experiment Sation, and in charge of investigations of stem rust of wheat and other cereals in cooperation with the Office of Cereal Investigations, U. S. Department of Agriculture, arrived in Washington on November 27 on his return from attendance at the meetings of the Australian Association for the Advancement of Science. Dr. Stakman left the University of Minnesota in July and was present at the meetings held successively in Melbourne, Victoria, and Sydney, New South Wales, covering a period of nearly three weeks. While in Australia he made trips into the wheat-growing areas of the States named. He returned to America via the Suez Canal, and made stops in Egypt, France, and England.

The Department of Agronomy and Agricultural Chemistry of the North Dakota Agricultural College displayed an educational exhibit at the International Grain and Hay Show held in Chicago, December 1st to 8th, in connection with the International Live Stock Exposition. The North Dakota exhibit was entitled "King Corn is Conquering in North Dakota." It showed graphically the rise in corn acreage from about 25,000 acres thirty years ago to about 750,000 acres in 1923. The exhibit also showed entire plants of a dozen locally adapted varieties of corn suited to the northern zone of agriculture, together with comparative yields and rates of maturing the same.

J. T. Sarvis, Assistant Agronomist of the Office of Dry-Land Agriculture Investigations, Bureau of Plant Industry, United States Department of Agriculture, who is stationed at the Northern Great Plains field station at Mandan, North Dakota is the author of U. S. D. A. Department Bulletin No. 1170 entitled "Effects of Different Systems and Intensities of Grazing upon the Native Vegetation of the Northern Great Plains Field Station." This bulletin recites the results of six years of grazing experiments on native prairie pasture in western North Dakota. The experiment is conducted co-operatively with the Department of Animal Husbandry of the North Dakota Agricultural College.

Stanley W. Cosby, Research Associate in Soil Technology, University of California, is on leave of absence until January 1, 1924, in Baja California, Mexico, making a reconnaissance soil survey of some 300,000 acres of land lying on the Colorado Delta and in the Laguna Salada Basin. The Mexican Government is planning to bring this region under irrigation and requested this survey. Professors C. F. Shaw and W. W. Weir of the Division of Soil Technology, are making a brief visit to Baja California for the purpose of studying the possi-

bility of reclaiming some of the alkali land lying in the Laguna Salada district.

T. E. Odland, Assistant Professor of Agronomy at the West Virginia Agricultural Experiment Station is on leave of absence for the current year to pursue graduate studies at Cornell University.

H. B. Sprague, of the University of Nebraska, has recently become associated with the Department of Agronomy of the New Jersey Station. Mr. Sprague obtained his Master's degree at Nebraska last June and will continue his graduate work in the New Jersey Station.

The Departments of Agronony and Agricultural Economics of the New Jersey Station, which were formerly associated as one department, have been reorganized as separate departments beginning July, 192?

At the Clemson Agricultural College, South Carolina, F. H. Robinson, a graduate of the University of Tennessee, and D. G. Sturkie, a graduate of Iowa State College, have been appointed as Assistant Professors of Agronomy; and J. D. Warner, a graduate of Clemson and of the University of Kentucky as Assistant Station Agronomist. P. H. Senn, Extension Specialist in Plant Breeding has resigned to enter commercial work; Leander Howell, assistant Professor of Agronomy has resigned to enter upon graduate work at the University of Wisconsin; and G. H. Collings, Assistant Professor of Agronomy, is on leave for graduate work at Rutgers College.

WANTED—AN "EASY MARK"

(NOTE—The following is a brief summary of a letter recently received by the Editor, as Director of a State Agricultural Experiment Station, by registered mail from abroad.)

An "inventor" in a European country wishes to dispose of the right to patent in America the "Aeronautic" method of setting agricultural plants, shrubs, trees and the like in difficultly accessible places, and in such a way that they will be self-nourished until natural conditions for their support become favorable. The proposed method is to put the seed or young plant into a perforated conical metal bag, which is filled with food for the young plant, sufficient for it to grow up and take root in firm ground, the bag is to be provided at the top with a vane to support the plant and direct the course of the apparatus when it is dropped from an aeroplane and at the bottom with a metal point to make it penetrate the earth.

The author adds: "The method is new, because aeronautic was as yet only applied to transport or destruction. If one wishes to buy the right to make application for patent for the same subject (agriculture, as manuring, sowing, planting by aeronautic), I awate propositions and it would be useful to state to me the character and magnitude of the plants that have to be sown in this way."

STANDING COMMITTEES FOR 1924

President Miller has appointed the following as members of the several standing committees of the Society for the year 1924:

COMMITTEE ON TERMINOLOGY

C. V. Piper, *Chairman* C. R. Ball, H. L. Shantz.

COMMITTEE ON STANDARDIZATION OF FIELD EXPERIMENTS

S. C. Salmon, *Chairman*, H. H. Love, C. A. Mooers.
T. A. Kiesselbach, A. C. Arny.

COMMITTEE ON VARIETAL STANDARDIZATION

H. K. Hayes, *Chairman*, E. F. Gaines, Geo. Stewart
J. H. Parker, R. G. Wiggans J. Allen Clark
L. H. Smith, H. G. Hastings, A. B. Conner.

COMMITTEE ON INTERCOLLEGIATE GRAIN JUDGING CONTESTS

A. C. Arny, *Chairman*, S. C. Salmon, John Pieper.

COMMITTEE ON TEACHING METHODS IN SOILS AND CROPS

W. C. Etheridge, *Chairman*, H. O. Buckman J. O. Morgan.
(Subcommittees to be selected)

COMMITTEE ON HONORARY MEMBERS, FELLOWSHIPS. AND PUBLICATIONS

J. G. Lipman, *Chairman*, R. W. Thatcher, C. A. Mooers,
P. E. Brown

COMMITTEE ON COOPERATION WITH THE NATIONAL RESEARCH COUNCIL

C. V. Piper, C. F. Marbut, C. W. Warburton, A. G. McCall,
A. C. Arny.
(Chairman to be elected by the Committee)

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REPORT OF THE ADVISORY COMMITTEE OF THE AMERICAN SOCIETY OF AGRONOMY[1]

J. G. Lipman[2]

The American Society of Agronomy is represented in the National Research Council by an Advisory Committee. The following report of this committee for the year 1923, deals with three items, namely: (1) the participation of American investigators in the program of the Fourth International Conference of Soil Science; (2) the organization and supervision of sulphur research projects; (3) the investigation of problems having to do with the salt requirements of plants.

THE INTERNATIONAL CONFERENCE OF SOIL SCIENCE

The Third International Conference of Soil Science was held at Prague, Czechoslovakia, in April, 1922. The United States of America was represented by C. F. Marbut, of the U. S. Department of Agriculture, and by the Chairman of this Committee. Before the adjournment of the sessions of the conference plans were made for the organization of a Fourth Conference, which is to be held in 1924. Both of the American representatives were assigned places on important committees. The writer was asked to organize the program of soil biochemistry and microbiology for North and South America and Asia. In accepting the responsibility, he recognized that representation in the Fourth International Conference should be from an organized group of American investigators. Hence, he communicated with the President of the American Society of Agronomy and with the Chairman of the Division of Biology and Agriculture of the National Research Council. President Sidney B. Haskell, of

[1]Prepared for but not presented at the annual meeting of the Society. Received for publication December 28, 1923.
[2]Chairman of the committee.

the American Society of Agronomy, met C. F. Marbut and the writer in New York City on July 16, 1923. The representation of American soil investigators and agronomists in The Fourth International Conference was considered, and it was decided that the American Society of Agronomy and the Association of Soil Survey Workers should be asked to name an American Organization Committee which would be representative of the two associations and of the different agricultural regions in the United States. Accordingly, a committee consisting of C. F. Marbut, F. J. Alway, F. E. Bear, P. E. Brown, A. G. McCall, M. M. McCool, C. F. Shaw, and J. G. Lipman were asked to serve in this capacity. Aside from this general organization committee, there is a special Committee on Soil Biochemistry and Microbiology. At the request of the Executive Committee of the Fourth International Conference, the writer has associated with himself as members of this special committee, Doctors F. Löhnis, P. E. Brown, H. J. Conn, E. B. Fred, J. E. Greaves and S. A. Waksman. Information as to the personnel of these two committees was sent both to the National Research Council and to the General Secretary of the Fourth International Conference.

This Fourth International Conference is to be held in Rome, probably during the first half of May, 1924. A list of fourteen papers by American investigators has been included in the program of the Conference. The titles of the papers to be presented and the names of the authors are as follows:

1. Cellulose Decomposition by Various Groups of Soil Microorganisms. Selman A. Waksman and H. Heukelekian, New Jersey Agricultural Experiment Stations, New Brunswick, N. J.
2. Influence of Partial Sterilization of Soil upon the Numbers and Activities of Various Groups of Microorganisms. Selman A. Waksman and Robert L. Starkey, New Brunswick, N. J.
3. Bacteria Concerned in the Oxidation of Sulfur in the Soil. Jacob G. Lipman and Selman A. Waksman, New Brunswick, N. J.
4. Biological Investigation of Peat. Arao Itano, Massachusetts Agricultural Experiment Station, Amherst, Mass.
5. A Tentative Outline of Study of the Microbiology of Soils and Manures with Special Reference to the Methods in Soil Microbiology. Sleman A. Waksman, New Brunswick, N. J.
6. The Influence of Plant Growth upon the State of Aggregation of Soil Particles. R. V. Allison, New Brunswick, N. J.
7. The Significance of Soil Reaction in Controlling Nitrogen Fixation (Microbial Activity) in Soils. P. L. Gainey, Kansas State Agricultural College, Manhattan, Kan.
8. Progress of Sulfur Investigations in Northwestern United States. W. L. Powers, Oregon State Agrcultural College, Corvalis, Ore.

9. The Mineralization of Atmospheric Nitrogen in Nature by Biological Means. A. Bonazzi, Ohio Experiment Station, Wooster, Ohio.
10. The Influence of Irrigation Water on the Composition of Ash of Grains and Its Bearing on Soil Fertility. J. E. Greaves and E. G. Carter, Department of Bacteriology, Utah Agricultural Experiment Station, Logan, Utah.
11. The Influence of Continuous Cropping on Crop Production on the Prairie Soils of the Northern Great Plains of North America. H. L. Walster, Agricultural College, North Dakota.
12. Magnesia as a Factor in Soil Productiveness. W. W. Garner and J. E. McMurtrey, U. S. Department of Agriculture, Washington, D. C.
13. Effect of Crop Plants on Succeeding Crops in the Rotation with Special Reference to Tobacco. W. W. Garner and W. M. Lunn, Washington, D. C.
14. The Investigation of the Soil from the Point of view of the Physiology of the Plant. D. R. Hoagland, University of California, Berkeley, Calif.

The Fifth International Conference will, presumably, be held in the spring of 1926. The place of the meeting is to be determined later. It might be desirable to arrange, if possible, for holding this Conference in the United States. The Committee will appreciate suggestions concerning this.

THE SULFUR FELLOWSHIPS

In the winter of 1922, the Chairman of this Committee outlined to the Texas Gulf Sulphur Company a plan for the organization of sulphur research projects. At his suggestion, that Company offered to the National Research Council the sum of ten thousand dollars for the establishment of a suitable number of fellowships at a number of educational institutions in the United States. The Division of Biology and Agriculture of the National Research Council recommended the acceptance of the offer and the organization of a Sulphur Fellowship Committee to deal with the matter. Accordingly, Doctors A. G. McCall, R. W. Thatcher and H. L. Shantz were appointed members of such a committee. The writer feels that the Society is greatly indebted to the Sulphur Fellowships Committee, and particularly to its chairman, for having organized very efficiently the sulphur research projects. The report of the Sulphur Fellowships Committee of its activities for the year 1923 follows:

Report of Sulfur Fellowships Committee

The special Sulphur Fellowships Committee, appointed by the Advisory Board of the American Society of Agronomy, has continued its general supervision over the Sulphur Fellowships established last year through the National Research Council by the Texas Gulf Sulphur Company of New York City. The fund of $10,000 which was placed at the disposal of the committee was expended in the support of eight fellowships, each of which carried a stipend of $1,000 and an allowance of $200 for travel incurred in connection with the fellowship work.

After a considerable amount of correspondence and some travel by the chairman of the committee, the fellowships were assigned as follows:

1. South Carolina Fellowship—Clemson College, under the supervision of Director H. W. Barre.
The Use of Sulphur for the Control of Sweet Potato Diseases.
Holder of the fellowship, Jesse H. Huffington, B.Sc., University of Maryland.

2. Ohio Fellowship—Ohio State University, under supervision of Dr. Herbert Osborn.
The use of Sulphur for the Control of Soil Infesting Insects.
Holder of the Fellowship, J. W. Bulger, B.Sc., Ohio State University.

3. Michigan Fellowship—Michigan Agricultural College, under the supervision of Dr. O. H. Coons.
The Use of Sulphur in the Control of Potato Scab.
Holder of the Fellowships, H. B. Wedgeworth, B.Sc., Mississippi Agricultural College.

4. Canada Fellowship—University of Toronto, under the supervision of Dr. J. H. Faull.
The Use of Sulphur in the Control of Potato Scab.
Holder of the Fellowship, Miss Catherine Graham, B.Sc., University of Toronto.

5. Kansas Fellowship—Kansas Agricultural College, under the supervision of Dr. M. C. Sewell.
The Use of Sulphur as a Fertilizer for Alfalfa and other Legumes.
Holder of the Fellowship, O. C. Bruce, B.S.A., University of Missouri.

6. Washington Fellowship—Washington Experiment Station, under the direct supervision of Dr. J. R. Neller.
The Effect of Sulphur on Soil Fertility with Special Reference to the Growth of Legumes.
Holder of the Fellowship, L. W. Erdman, Ph.D., Iowa State College of Agriculture.

7. California Fellowship—Citrus Experiment Station at Riverside, under the direct supervision of Dr. W. P. Kelley.
The Effect of Sulphur on Alkali Soils.
Holder of the Fellowship, C. D. Samuels, M.Sc., University of Wisconsin.

8. Florida Fellowship—Florida Experiment Station, under the direct supervision of Prof. J. B. Watson.
The Use of Sulphur in the Control of Nematodes.
Holder of the Fellowship, R. L. Trigg, B.Sc., Mississippi Agricultural College.

During the first year, work on these fellowships progressed without any change in personnel or other interruptions. The close of the year, however, was marked by the resignation of O. C. Bruce, the holder of the Kansas Fellowship, and of W. L. Erdman, holder of the Washington Fellowship, and the decision of the Texas Gulf Sulphur Company to reduce their appropriation from $10,000 to $7,000. In view of the resignation of Messrs. Bruce and Erdman, and the reduction in the appropriation, the Kansas and Washington Fellowships were discontinued. The six remaining fellowships were assigned to the same institutions for the second year and the fellows re-appointed. Recently the work at the Florida Experiment Station has been interrupted temporarily by the resignation of Mr. Trigg, the holder of the fellowships.

The committee has been gratified to note the interest shown in these fellowships, and the hearty co-operation of all of the institutions concerned.

Respectfully submitted,

A. G. McCall *Chairman*
R. W. Thatcher
H. L. Shantz

WORK OF THE SUB-COMMITTEE ON THE SALT REQUIREMENTS OF PLANTS

It is the belief of the Sub-committee on the Salt Requirements of Plants that it would be well to ask the National Research Council to relieve the committee of further responsibility. The report of the committee is herewith given.

MEMORANDUM TO THE ADVISORY BOARD OF THE AMERICAN SOCIETY OF AGRONOMY CONCERNING THE WORK OF THE SUB-COMMITTEE ON THE SALT REQUIREMENT OF PLANTS

The Committee on the Salt Requirement of Plants was organized in 1916, under the auspices of the National Research Council, with Dr. B. E. Livingston of Johns Hopkins University as chairman. In 1921 at his own request, Dr. Livingston was relieved of the chairmanship and the committee was re-organized as a sub-committee to be sponsored by some outside organization.

By the action of the American Society of Agronomy at the New Orleans meeting (November, 1921) and by a similar action of the Physiological Section of the Botanical Society of America at the Toronto meeting (December, 1921), the sub-committee was sponsored by these societies and its activities placed under the general control of the Advisory Boards of these two organizations. The Board of the Botanical Society at once designated Charles A. Shull of the University of Chicago, and B. E. Livingston of Johns Hopkins University, as its representatives, and the Advisory Board of the American Society of Agronomy selected H. L. Shantz of the United States Department of Agriculture, and A. G. McCall of the University of Maryland, the latter being designated as Chairman of the sub-committee.

For various reasons the re-organized sub-committee has found it to be not feasible to proceed according to the "Plan" projected by the original committee and for this reason has confined its activities to efforts designed to encourage various institutions to engage in experimental solution or sand-culture studies more or less along the lines proposed by the original committee.

As the direct or indirect result of the activities of the Committee, the following institutions have engaged in some phase of the solution and sand culture work.

1. Johns Hopkins University.
2. University of Maryland Experiment Station.
3. New Jersey Experiment Station.
4. University of Wisconsin.
5. University of California.
6. University of Illinois.
7. Syracuse University.
8. University of Pennsylvania.
9. Leland Stanford, Jr. University.
10. Michigan Agricultural College.
11. Cornell University.
12. Iowa State College of Agriculture.
13. Kansas Agricultural College.
14. University of the Philippine Islands.

A review of the literature shows that the results of the various workers have been recorded in more than fifty papers read before the various scientific societies and published in scientific journals and experiment station bulletins.

Inquiries and correspondence from other institutions, both in this country and abroad, indicates that workers at other institutions are interested and are making use of our suggestions in working on some special phases of plant nutrition work.

Material is being prepared for publication of a paper or a monograph in the near future, which will give a brief resumé of the present status of the recent work in plant nutrition, together with a complete bibliography.

The chairman has been hopeful that funds might be secured through the National Research Council, or from some other source, whereby the committee would be able to establish a number of fellowships, the work of which might be co-ordinated and directed toward the solution of some of the more fundamental problems connected with the nutrition of agricultural plants. In the absence of such a fund, the committee has been forced to limit its activities and to be content to serve as a clearing-house for information concerning plant nutrition work.

We request from the Advisory Board an expression of its opinion of the advisability of making a final report to the National Research Council, with a request that the present Committee be relieved of further responsibility. In the absence of sufficient funds to offer substantial encouragement to institutions and to individuals, there is very little that can be done by your committee except to continue a nominal existence and offer moral encouragement from time to time as occasion may arise.

Respectfully submitted,
A. G. McCall, *Chairman*.

THE ORGANIZATION OF A GENERAL INTRODUCTORY COURSE IN SOILS WITH SPECIAL REFERENCE TO THE LABORATORY EXERCISES[1]

H. O. Buckman[2], P. E. Karraker[3] and R. I. Throckmorton[4]

Early in 1923, a sub-committee of the American Society of Agronomy was appointed to study the laboratory work in elementary soils as given at the several agricultural colleges in the United States. Late in the spring requests for copies of the current laboratory outlines were sent out accompanied by a questionnaire. Most of the material requested was received by July 1. Replies to the questionnaire were received from thirty-nine institutions teaching courses in soils. Twenty-three sent laboratory outlines to the committee, while nine failed to answer letters addressed to them. Of the sixteen departments answering the questionnaire, but sending no laboratory outlines, practically all were making drastic changes in their laboratory procedure and felt that they had little of a constructive nature to offer.

[1]Report of a sub-committee on agronomic teaching of the American Society of Agronomy. Received for publication January 6, 1923.
[2]Professor of Soil Technology, Cornell University, Ithaca, N. Y.
[3]Associate Professor of Soils, University of Kentucky, Lexington, Kentucky.
[4]Professor of Soils, Kansas Agricultural College, Manhattan Kan.

Of the thirty-nine departments which answered the questionnaire, eighteen are giving a complete general course in edaphology, or, in other words, applied soil science, covering one term. Twenty-one give, as their first course, instruction consisting principally of soil physics. Such a course is followed in most instances by courses in soil fertility and sometimes by courses dealing with soil management or related work.

As might be expected the hours of credit per semester for the elementary course are quite variable. Three percent of the colleges give a 6-hour course; 27 percent, a 5-hour course; 40 percent, a 4-hour; 27 percent, 3 hours; and 3 percent, 2 hours a week. In most cases the two-, three-, and four-hour courses are not general in their scope but are followed by additional work during the next term. The tendency at present seems to be towards a four-hour course, consisting of three lectures and one laboratory per week, or of two lectures, one recitation and one laboratory period.

Of the departments reporting, nineteen give lectures distinct from the recitation work; sixteen combine lectures and recitations or laboratory and recitation; while four give no lectures at all. Three lectures per week seems to be the most common practice. Thirty of the thirty-nine colleges canvassed utilize recitations in some form, altho only thirteen have distinct recitation sections. With the recitations, two hours per week seems to be the most common plan, altho one hour occurs in one-third of the cases studied. In 74 percent of the institutions where recitations are used in some form, the work is conducted by men of a professorial rank, in 10% by professors and instructors, and in 16% of the cases by instructors and assistants alone.

Laboratory practice in the teaching of elementary edaphology is made use of by all of the thirty-nine institutions studied. The actual hours of work range from two to six per week altho two and one-half to three hours are most common. In 20 percent of the departments four hours are required. In two-thirds of the colleges, the laboratories appear to be conducted by teachers of professorial rank, usually without the aid of an instructor or an assistant. In one-third of the cases the laboratory seems to be entirely in the hands of an instructor or an assistant.

The data as presented above, while they indicate a great variability in the organization and the handling of the elementary instruction, are highly encouraging. There seems to be a rather marked tendency towards standardization; perhaps as much as could be expected, considering the differences in student preparation and viewpoint and

the variability in the agriculture of the sections of the country represented. The fact that such a large proportion of the recitation and laboratory work is personally conducted by professors is somewhat surprising. This is certainly a situation exactly opposite to that existing in the elementary courses offered in the older sciences.

The analysis of the replies to the questionnaire as outlined above was a much easier task than was the study of the laboratory exercises submitted to the committee. While the lectures and recitations as given in the various colleges are no doubt somewhat similar in organization and content, this cannot be considered as true of the laboratory instruction. The fullest opportunity occurs here for the widest imaginable variations. Agricultural conditions, number and preparation of the students, size of the laboratory, amount and range of the apparatus, and the scope of the course are a few of the outstanding contributory causes. As a consequence, the committee can do little but comment in a general and rather disappointing manner on the results of its study of this phase of the problem.

The most desirable laboratory exercises, as indicated by the outlines submitted, and listed without regard to their possible laboratory sequence, are submitted as follows. It should be noted that several of the items involve more than one laboratory period.

Study of soil minerals (fertility viewpoint).

Weathering and soil formation (directed towards soil processes).

Qualitative study of important soil constitutents (such as K, P and Ca).

Soil organic matter (nature, amount, nitrogen content, etc.).

Volume weight determinations (with specific gravity and pore space calculations).

Mechanical analysis (simple form) and soil particle study (with practice in the naming of soils in field condition).

Temperature studies (with practical relationships, especially to soil moisture).

Soil survey (study of maps and reports, and also simple field work when conditions justify).

Absorption by soils (principles of absorption with practical relations).

Soil acidity tests (thorough practice, especially on qualitative methods).

Bacterial activities (nitrification is easily handled).

Alkali and alkali soils (for arid and semi-arid sections).

Lime and liming (forms and characteristics of lime).

Fertilizers (forms, characteristics and identification tests).

Lime, fertilizer and general fertility problems.

Opportune field trips to study various practical phases of soil condition and management.

An effective spur to the interest taken by students in laboratory exercises such as above suggested is to be found in the use of short written quizzes at the beginning of each laboratory period. In the experience of the committee, these tests on the work of the preceding exercise are preferable to the report methods now followed in most institutions. Such a system of quizzes not only tends to keep the class thinking during the ensuing week of the principles developed in the preceding period, but at the same time fixes the important points of theory and practice in the student's mind rather than burying them in a report. The influence of the written quizzes in discouraging tardiness is by no means an unimportant factor. Many students even prefer to come early in order to have ample time to dispose of the quiz to their satisfaction. Moreover, such a plan aids in the correlation of the laboratory with the lectures and the recitations, since important laboratory principles may be anticipated and reviewed in these branches of the course.

Because of the complexities already mentioned, the committee deemed it inadvisable at the present time to go farther in a construction way. In order to be fully effective, laboratory instruction must be intimately related to the lectures and recitations. Since the lecture and recitation work given at the individual colleges is by no means standardized the construction of even tentative laboratory outlines which will have more than local application seems to be utterly impossible. The time is hardly ripe seriously to make such an attempt. A few years hence such a publication may be ventured.

The laboratory outlines as submitted to the committee were probably more enlightening concerning what should not be done in a soil laboratory rather than what is really advisable. For instance, in some laboratories the determination of the amounts of phosphoric acid, nitrogen, and other nutrient elements is given considerable prominence. Such teaching is of doubtful value, especially from the practical standpoint, since data thus obtained are difficult to apply. Moreover, the students in many cases are inadequately prepared for such work. Again, a soil laboratory does not appear to be the best place to teach routine chemical methods, especially when there is undoubtedly plenty of material of a more valuable and legitimate nature available for soil teaching. The determination of

loss on ignition and of the specific gravity and the hygroscopic coefficient of soils are open to the same objections as above registered. The coefficient of evaporation from soils seems to be another rather unfruitful exercise, unless given a very practical bearing.

The old percolation experiment, together with measurements as to capillary rise of water and the flow of air thru different soils, seems superfluous at the present time. Unless the student has had absolutely no training in physics, such conceptions, together with their field significance, are readily grasped and really need little more than clear class-room consideration. As everyone knows such exercises fall far short of representing actual field conditions. They are so artificial, as well as superficial, that the principles involved can best be presented in other ways.

The demonstration in the laboratory that well established mulches will conserve moisture belongs in the same category as those just discussed; as also does the determination of the conductivity of heat thru soils. In the case of mulches, it is the comparison of the sacrifice of water during formation with the probable check of later evaporation that needs emphasis rather than the simple fact that mulches when once established will conserve moisture. The latter phenomenon is so simple that a class-room explanation is usually adequate.

Tenacity tests of soils, especially in relation to added lime, are not only of little practical value but may actually become misleading if left in the hands of inexperienced instructors or assistants. A soil sample, when submitted to the tenacity test, is certainly not in a normal field condition. Moreover, lime, when applied in practice, probably has but little direct effect on the physical character of the soil, at least in the majority of cases.

Many institutions are studying soil minerals as an early laboratory exercise. As would be expected the study in most cases is made from the fertility standpoint. In the opinion of the committee, a consideration from any other angle is entirely unwarranted. In many cases, this exercise is accompanied or followed by a detailed study of the common rocks. If a course in geology is a prerequisite such rock study is obviously a waste of time and may even distract the student's attention to a certain degree. Under such conditions the relation of rocks to edaphology might well be reserved for lecture or recitation consideration. Even if the instruction in soils has not been preceded by a course in elementary geology, an exercise on rocks is questionable, unless reduced to a minimum. The inorganic fragments of the soil are in most cases separate minerals or weathering

products and not pieces of rock. Logically, the attention should be directed continuously towards the soil minerals, rather than to the rocks from which they came. A study of the latter, at least in any detail, more properly belongs to the underlying science rather than to considerations of an edaphological nature. Moreover, in a study of rocks the fertility viewpoint is more difficult to preserve and probably already has been fully and adequately emphasized in a preceding consideration of soil minerals.

On the basis of the difficulties already emphasized, the committee feels justified in offering nothing more constructive than the tentative list of exercises already suggested. Even the sequence of exercises in such a list is rather uncertain, because of the variable conditions which exist at the several colleges. While destructive criticisms are perhaps the most prominent features of this report, the authors hope that such deprecation will serve to direct the reader's attention more particularly than otherwise towards those exercises and procedures that deserve further study and development.

WEED VALUE[1]

E. G. CAMPBELL[2]

It is not the purpose of this paper to completely exonerate weeds on the basis of their values, but rather to suggest a new attitude toward them.

Every well regulated farm is operated toward two objectives; present crop income, and future possibilities. Wild plants of the open fields take an unbidden part in the determination of these two purposes.

The most vital point in both present and future crop yield is soil productivity, and this is dependent upon physical composition and chemical balance. One of the limiting factors in crop production is nitrogen, which normally becomes available, to ordinary field plants, only in the form of nitrate. But nitrates, being readily soluble in soil water, are easily leachable, Therefore, when a given amount of nitrate is applied to the soil, for the purpose of increasing crop production, it is possible that some of it will have leached to a depth below the reach of ordinary farm crops before they absorb enough for maximum growth and yield.

The work of conserving and maintaining soil nitrogen is one of the

[1]Contribution from the Department of Agronomy, Purdue University, Lafayette, Indiana. Received for publication December 4, 1923.
[2]Assistant Professor of Agricultural Botany.

most perplexing problems of modern agriculture. The Virgin soils of the United States, once so universally sought and so freely secured, are no longer easily obtainable. The old time "new grounds" of the farm were made rich by the deposits of either a grass-land or a woodland vegetation. To-day there is an open field flora whose members farmers choose to call weeds. Recently much has been said about the many million dollars lost annually through the growth of weeds, and many eradicative methods have been formulated, but little consideration has been given to the merits of this "savage flora" of the open fields.

The problem of weed utilization on the farm involves, in addition to the varying abilities to absorb nitrates, two ecological factors: (1) the relative working root depth of cultivated plants and contemporary weeds; and (2) seasonal and time relation of maximum activity of crop plants and wild species of the farm.

(1) In casually observing the root systems of contemporary species the following conditions are noted: (a) Most perennial roots are deeply anchored and have a thick corklike covering. (b) The roots of biennials are generally deeply set, but they are less thickly coated. (c) Annuals and winter annuals are not deeply rooted and cutinization is slight. (Plate I).

Roots of native species are found to extend more deeply than those of crop plants in the same locality; but in regard to nitrate absorption, only feeding roots are involved and these extend much deeper than the ordinarily observed bulky portions.

Root depth varies according to the natural water supply of the soil and the location of nutrient salts (5, 6)[3]. Crop plants have been known to absorb nitrates from a great depth: Ten Eyck (4) has found, in North Dakota, the roots of Irish potato extending three feet deep, corn three and one-half, sugar beet three and one-half, and wheat four feet. Rotmestrov (3) has shown that in the Odessa field of Russia, Irish potato roots extend to a depth of two feet, corn three and three-fourths, beet three and three-fourths and wheat three and one-third feet. The author has found in the vicinity of Purdue University, that the root depth of wild winter annuals exceed that of cultivated plants of the same age. (See Figure 1). This conclusion, however, is only tentative and suggestive, for, while the supporting data involve a great number of root excavations, growing seasons of only two years (1922 and 1923) were covered. If, however, it should prove to be a fact that in general, wild species exceed cultivated plants in depth of absorbing system, it may be con-

[3]Reference by number is to "Literature Cited," p. 96.

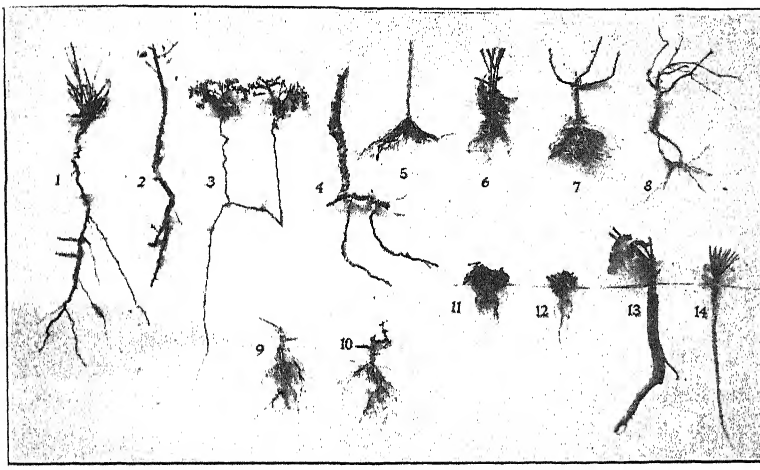

PLATE 1

The root systems of a few farm plants and several weeds.
(Spaded up with no effort to secure complete spread or depth)

1. Solanum carolinense (Horse Nettle).
2. Physalis heterophylla (Ground Cherry).
3. Cirsium arvense (Canada Thistle).
4. Asclepias syriaca (Common Milkweed).
5. Corn.
6. Wheat.
7. Egg Plant.
8. Cucumber.
9. Chenopodium album (Lamb's Quarter).
10. Aramanthus retroflexus (Pigweed).
11. Erigeron annuus (White top).
12. Lactuca scariola (Prickley Lettuce).
13. Arctum minus (Burdock).
14. Daucus Carota (Wild Carrot).

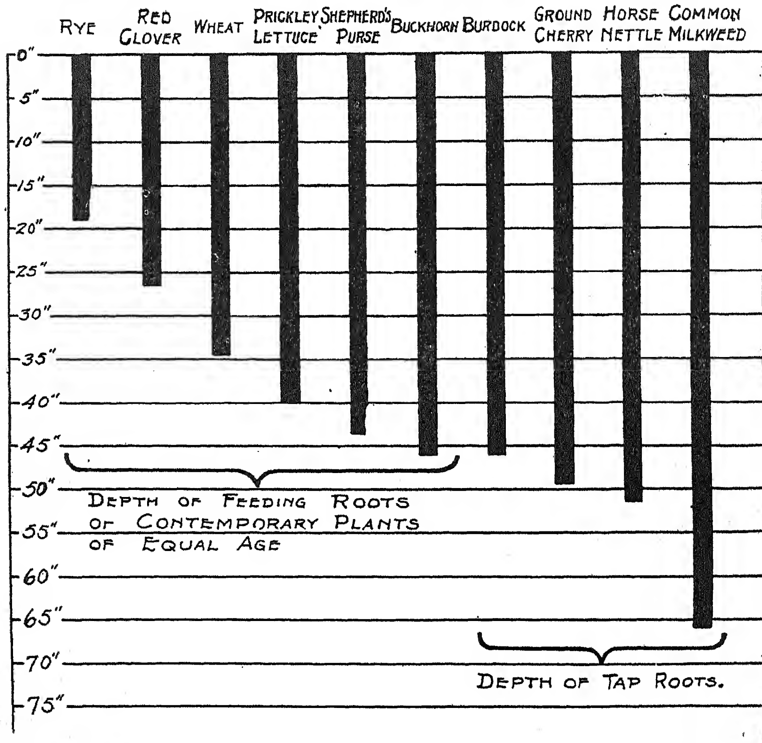

FIG. 1

cluded that deeply leached nitrates can, in part, be returned to the upper surface layers of the land by the growth and decay of certain species of weeds.

Biennials, after the first few weeks of their existence, feed mainly below the working depth of cultivated plants (Plate I). If such weeds are plowed under in the spring of their second year, before they bloom, it is natural to suppose that thereby considerable food materials are retained in the surface layers of the soil, which otherwise would have been lost.

Deep rooted perennials feed mainly at an extreme depth. In this group of weeds little or no absorption goes on in the top foot or two of the soil, because of the cutinized or suberized root cortex. Such plants do not store nitrates but are rich in total nitrogen. Deep-rooted perennial weeds, therefore, may be outlawed because they shade, crowd, hinder in harvesting, or lower the value, of the cultivated crop.

(2) With some weeds, absorption of nitrates begins very early in the spring, by the time young shoots reach the surface, and continue until late in the fall. Among these are curled leaved dock, burdock, wild carrot, etc. Such weeds are not only deeply set, but in duration of absorption, they both precede and succeed the growing season of most crops.

The heavy stands of pigweeds and other annuals, that cover the cultivated fields after each rain, serve as nitrate holders. If these weeds are clipped before they crowd or shade the crops, no harm is done and the soil is not only benefitted physically, but some nitrate nitrogen and considerable nitrogen in other forms are added to the surface of the soil, which will become available for future crops. It appears that the early annuals, which cover the ground before it is broken in the spring, should increase the yield of the oncoming crop. Some late annuals, such as ragweeds in the stubble field, lambs quarter and pigweed in the corn field, etc., draw food materials back to the surface at a time when no cultivated plants are present, and thus retain what otherwise would have been lost to future crops.

Winter annuals begin their growth in early fall, either in idle fields or in company with such winter annual crops as wheat and rye. When rye is to be used as a green manure crop, the presence of winter annual weeds, according to recent analyses by the author, is slightly beneficial if they are turned under prior to blooming. If winter annuals are left to grow on idle fields which are to be put into cultivated crops in early spring, the indications are that a considerable advantage is gained.

The spontaneous weed group, of waste places and road sides, in spite of the estimated expense of mowing (1) is of inestimable value to mankind. By these, a vast acreage is constantly being redeemed and restored to cultivation, and untold stretches of highway are held intact against the destructive physical forces of nature.

In this day of mechanical efficiency and crop rotation, farmers may feel justified in ignoring nature's professed aid in conserving the texture and nitrogen of the soil. Nevertheless, all well balanced systems of farm management will involve methods of weed control, and the expensive and almost futile efforts at weed eradication will be restricted to the uncontrolables, disease carriers, poison containers and spine producers.

Recently, Lyon, Bizzell and Wilson have published a most illuminating paper (2) in which they have made visible new problems in weed values on the farm, entirely aside from root depth and maturity relations.

LITERATURE CITED

1. HANSEN, A. A. The toll of weeds in Indiana. Proc. Ind. Acad. Sci. 105–109 1921.
2. LYON, T. L., BIZZELL, J. A., and WILSON, B. D. The depressive influence of higher plants on the accumulation of nitrates in the soil. Jour. Am. Soc. Agron., 15: 457–467. 1923.
3. ROTMISTROV, V. Root system of cultivated plants of one year's growth. Rept. Odessa Expt. Field, 25:— 1909.
4. TENEYCK, A. M. A study of the root system of cultivated plants. N. D. Agr. Expt. Sta. Bul. 64. 1900.
   ———. The roots of plants. N. D. Agr. Expt. Sta. Bul. 127. 1905.
5. WEAVER, J. E. Ecological relation of roots. Carnegie Inst. of Wash., Pub. No. 236. 1919.
6. WEAVER, J. E. *et al.* Development and activities of roots or crop plants. Carnegie Inst. of Wash. Pub. No. 316. 1922.

AVAILABILITY OF THE PHOSPHORUS OF FLOATS AS INFLUENCED BY INCORPORATION OF FARM MANURE IN THE SOIL[1]

T. L. LYON AND H. C. BUCKMAN[2]

It has frequently been stated that the decomposition of organic matter in contact with raw rock phosphate increases the solubility of this material and makes its phosphorus more readily available to growing plants. Experiments in which the degree of availability was measured by chemical means, when phosphate rock was applied to soil, have not usually indicated that increased solubility resulted from the application of organic matter. When availability has been measured by crop growth, the returns have been more favorable to the theory that decomposing organic matter increases the availability floats. The literature of the subject as been so comprehensively reviewed by Waggaman, Wagner, and Gardiner (1)[3] that it is unnecessary to discuss here the results of preceding investigations.

We ventured to add another experiment to the very considerable number dealing with this subject because more evidence appeared to be needed and in the hope that it might be possible to supply some that would be relatively low in experimental error. With the latter purpose in view, careful attention was given to the technique and the final data were all subjected to mathematical tests of their significance.

[1]Contribution from the Department of Agronomy, Cornell University, Ithaca, N. Y. Received for publication December 15, 1923.
[2]Professor of Soil Technology.
[3]Reference by number is to "Literature Cited," p. 103.

PLAN OF EXPERIMENT

The experiment was conducted on Caldwell Field, the soil of which is Dunkirk clay loam, the origin and physical structure of which has been described by Bonsteel, Fippin and Carter (2) and the chemical composition by Lyon and Bizzell (3). The tests were made on field plats 1/100 acre in size, the dimensions being 43.6 feet long and 10 feet wide. There were two-foot spaces between the plats, which were covered with the same crops as were the plats, but were cleared of all vegetation before harvest. A drain tile ran the length of one side of each plat. Every third plat was used as a check and received no fertilizer treatment of any kind. Each test treatment was applied to four separate plats, these replicates being distributed systematically over the area used for the experiment. Planted margins were maintained on both ends of all plats and these were dealt with as were the spaces between the plats.

One set of plats received farm manure as a basic treatment. Of these, all but four were given applications of acid phosphate or Florida ground phosphate rock, the quantities varying with different plats. Another set of plats received no farm manure, but a basic treatment of nitrate of soda and muriate of potash. To all but four of the latter set of plats acid phosphate or ground Florida rock was applied, in varying quantities.

TABLE 1. *Test Treatments in the Experiment.*

Plat Numbers	Treatments at annual rate per acre
1602, 1620, 1809, 1827	Manure alone
1603, 1621, 1811, 1831	Manure and 100 lbs. acid phosphate
1606, 1624, 1814, 1834	Manure and 200 lbs. acid phosphate
1635, 1829*	Manure and 400 lbs. acid phosphate
1611, 1629, 1818, 1838	Manure and 200 lbs. floats
1612, 1630, 1802, 1820	Manure and 400 lbs. floats
1615, 1633, 1805, 1823	Manure and 800 lbs. floats
1617, 1637, 1806, 1824	Manure and 2400 lbs. floats
1609, 1627, 1817, 1837	Nitrogen and potassium alone
1605, 1623, 1812, 1832	N, K, and 100 lbs. acid phosphate
1608, 1626, 1815, 1835	N, K, and 200 lbs. acid phosphate
1614, 1632, 1803, 1821	N, K, and 400 lbs. floats
1618, 1638, 1808, 1826	N, K, and 2400 lbs. floats

*These plats were in duplicate instead of quadruplicate.

The applications of farm manure were made at the annual rate of 7 tons to the acre, the crops actually receiving the treatments being corn, wheat and barley. Nitrate of soda and muriate of potash were applied at the rate of 200 pounds of the former and 50 pounds of the latter to the acre annually. The only crop that did not receive nitrate of soda was clover. All received muriate of potash.

The crops grown were as follows:

Crop	Year	Crop	Year	Crop	Year
Corn	1914	Corn	1918	Corn	1922
Oats	1915	Oats	1919		
Wheat	1916	Barley	1920		
Hay	1917	Hay	1921		

The reason for introducing barley in 1920 was because the wheat planted in the fall of 1919 partly winter killed and the stand was injured. The land was replowed in the spring and barley planted. With the exception of the wheat that was winter killed in 1919–20. the crops all grew normally.

PRESENTATION OF THE RESULTS

In preparing the data for presentation, the first step was to find the calculated yield for each test plat for each year. The calculated yield was derived from the two nearest check plats on the assumption that the land varied uniformly from one check plat to the other. Supposing that the following data were obtained, the calculations for increase due to fertilizer treatment would be as follows:

Plats	Actual yield	Calculated yield	Increase
Plat 10 Check	40 lbs.		
" 11 Treated	70 lbs.	42 lbs.	28 lbs.
" 12 "	75 lbs.	44 lbs.	31 lbs.
" 13 Check	46 lbs.		

The average increase over the calculated yield for each set of plats receiving the same treatment was then found for each year, and from this, the average for the nine years was obtained. Table 2 contains a statement of the increased actual yield for each set of treated plats over their calculated yield, expressed in pounds to the acre annually for an average of nine years. In computing this table the weight of the total crop was used; as, for instance, combined grain and straw of the small grains and the entire weight of ears and stover for the corn crops.

The extreme right hand column of Table 2 shows the odds in favor of the increase in yield being due to the fertilizer treatment and not to accidental causes. The odds have been calculated by the method of Student (4) in which the average yields for the four plats having

replicated treatments are compared with the calculated yields for the same plats. Odds of 30:1 are usually considered to indicate reasonable certainty, altho greater odds are desirable.

TABLE 2. *Excess of actual yield over calculated yield for each fertilizer treatment and odds indicating that increase is due to treatment.*
(The data are expressed in average annual total yield.)

Phosphorus applications, in pounds to the acre.	Excess yield in pounds to the acre	Odds
Manure alone	1910	478:1
Manure+100 pounds of acid phosphate	2120	503:1
Manure+200 pounds of acid phosphate	2230	763:1
Manure+400 pounds of acid phosphate	2740	1131:1
Manure+200 pounds of floats	2230	953:1
Manure+400 pounds of floats	2330	826:1
Manure+800 pounds of floats	2720	1922:1
Manure+2400 pounds of floats	2650	1314:1
Nitrogen and potassium alone	1490	2905:1
N and K+100 pounds of acid phosphate	1710	9999:1
N and K+200 pounds of acid phosphate	1810	9999:1
N and K+400 pounds of floats	1870	9999:1
N and K+2400 pounds of floats	1710	9999:1

All plats, including checks, were limed with marl at the rate of four tons to the acre at the beginning of the experiment and later two tons of ground limestone were applied. Gypsum was added to all plats receiving floats, the quantity being equivalent to the sulfur contained in 200 pounds of acid phosphate.

Applications of acid phosphate were made for each crop, in quantities to be stated later. Floats were applied every three years. In both the tables of treatments the quantities are stated at the rate of annual applications. Thus the plats which are shown in the table to have received 200 pounds of floats annually had 1800 pounds applied to them in nine years. These were actually added at three different times at the rate of 600 pounds to the acre each time. This was done in the belief that there would be an advantage in having a large quantity of floats in the soil to be acted upon by natural solvents. It is not certain, however, that it would not have been better to have applied them annually.

Table 2 is germane to the discussion only because of the evidence it gives that up to the point at which the effects of the fertilizer treatments are compared with no fertilizer applications, there are increases in yields that are definite, and in the main, larger with increasing quantities of any one fertilizer treatment. Moreover, the increased yields may safely be considered to be due to the particular fertilizer treatments given, when the method of Student is taken as the criterion by which their significance is judged.

The method proposed by Student was used for testing the signifi-

cance of the results because it admits of the averaging of data accumulated thru a series of years. This method makes it possible to take as the number of observations, the yields for the nine years during which the experiment was in progress, the average for the four replicate plats being a single observation. The odds as expressed by Student's formula, indicate the significance of the average data of a number of years in terms of the treatments applied, the influence due to seasonal variation being minimized. While the applicability of existing mathematical methods for the proof or disproof of the reliability of field plat experiments of this kind is still a matter of some uncertainty, we consider it highly desirable to apply some one of the recognized methods to the data we have secured.

THE EFFECTS OF THE PHOSPHORUS CARRIERS

The next step is to compute the influence exerted by the various applications of phosphorus carriers as measured by crop yields. It has already been said that there were two basic treatments on each of which graduated quantities of the phosphorus carriers were superimposed. Farm manure constituted one basic treatment, and a mixture of nitrate of soda and muriate of potash the other. The manure furnished nitrogen and potassium in available form and probably some phosphorus as well as organic matter. It is the effect of this organic matter on the availability of the floats that it is proposed to measure. The basic treatment of nitrate of soda and muriate of potash was designed to offset, in part at least, the nitrogen and potassium of the manure.

Acid phosphate was applied in graduated quantities to test the need of the soil for phosphorus up to the point represented by 400 pounds of this carrier when used in addition to manure. The test of the effect of the organic matter on the availability of the phosphorus of the floats is based on the comparative yields obtained by the use of floats in addition to manure as compared with the use of floats in addition to nitrate of soda and muriate of potash. The figures for the yields of the phosphorus-treated plats over the plats receiving basic treatment only, are given in Table 3.

Considering first the manure treated plats it may be seen that the crop yields increased with each step in the treatment with acid phosphate. With floats, the crop yields increased with the graduated amounts up to 800 pounds to the acre. The availability of phosphorus in floats is in the order of the quantity applied just as it is in acid phosphate. A comparison of the soil response to the two carriers of phosphorus indicates a high degree of availability for the

TABLE 3. *Crop yields on phosphorus treated plats in excess of yields from plats receiving basic treatments only.*

(The data are expressed in average annual total yield.)

Phosphorus applications in pounds to the acre	Excess yield in pounds to the acre	Odds
Manure plus		
100 pounds acid phosphate	210	179:1
200 " " "	320	4693:1
400 " " "	830	195:1
200 " floats	320	596:1
400 " "	420	3648:1
800 " "	810	1120:1
2400 " "	740	914:1
Nitrate of soda and muriate of potash plus		
100 pounds acid phosphate	220	18:1
200 " " "	320	48:1
400 " floats	380	27:1
2400 " "	220	17:1

floats. The question may now be asked whether the decomposition of the manure is a factor in bringing about this availability.

Before attempting to answer this question let us consider the data from the plats that received a basic treatment of nitrate of soda and muriate of potash. On these plats acid phosphate increased the yield with each progressive application. The availability of the acid phosphate as was to be expected, does not appear to depend on the presence of manure. On the other hand, floats, without manure, showed no effect on yield beyond that exerted by the smaller application, which may be taken to indicate that its availability has not increased beyond that point. Comparing the effect of the floats on the manured and unmanured plats it may be seen that availability increases with increased applications on the former while it does not do so on the latter. The presence of manure being the deciding factor, this material must account for the greater availability of the floats on the manure-treated plats.

The criticism may be made that the data do not prove that a greater gain in yield could be obtained from applications of any form of phosphorus than was derived from the application of 400 pounds of floats and therefore that it is not certain that phosphorus was the limiting factor beyond that point on the plats not receiving manure and therefore it cannot be said positively that 2400 pounds as floats would have increased the yield if it had been more available. In reply to this, it may be said that the plats not receiving manure as a basic treatment were heavily fertilized with nitrate of soda and muriate of potash, which, if the phosphorus were available, would, it would appear, permit of yields commensurate with those on the manure-treated plats. Instead of such yields being obtained the

application of 400 pounds of floats resulted in only 380 pounds of crop on the plats not receiving manure while the same treatment gave 420 pounds on the plats to which manure was applied. The smaller yield on the non-manured plats may be taken to mean less available phosphorus.

Glancing at the table of odds, it will be noted that for the plats on which manure was used, the odds in favor of the increased yields being due to the phosphorus applied, were all in the hundreds. Where manure was not used, the odds were much smaller, and for the floats they are so small that it is not certain that any gain resulted from the use of that form of phosphorus. This serves to emphasize more strongly the lesser availability of the phosphorus of the floats when not incorporated with manure.

There are one or two other features of the experiment that may be noted. One of these is the very satisfactory returns from the use of floats when used on this soil in conjunction with manure. Another is the failure of floats to influence crop yields when used in excess of 800 pounds to the acre. This may have been due to the phosphorus ceasing to be the limiting factor when that point was reached or the organic matter, even on the manured soil, may not have been present in sufficient quantity to render more phosphorus available. It seems quite likely that the quantity of organic matter present in a soil or added to it, may cause different soils to respond differently to floats and also that the normal rate of decomposition, which varies with different soils, may be a controlling influence in the response of soils to floats.

TABLE 4.—*Yields of grain alone and of combined straw and stover in excess of yields of the same portions of crops on plats receiving basic treatments only*
(The data are expressed in average annual total yield.)

Phosphorus treatments in pounds to the acre	Excess yield of grain in pounds to the acre	Odds	Excess yield of straw and stover in pounds to the acre	Odds
Manure plus				
100 pounds acid phosphate	130	49:1	130	51:1
200 " " "	170	19.1	160	42.1
400 " " "	400	18:1	510	780:1
200 " floats	160	29:1	180	343:1
400 " "	210	53:1	230	4999:1
800 " "	300	162:1	530	152:1
2400 " "	320	53:1	480	503:1
$NaNO_3$ and KCl plus				
100 pounds acid phosphate	40	2:1	160	11:1
200 " " "	80	4:1	210	51:1
400 " floats	140	11:1	300	26:1
2400 " "	50	3:1	120	6:1

TABULATION OF DATA FROM GRAIN ALONE AND FROM COMBINED STRAW AND STOVER

The yields of threshed grain on these plats have been tabulated in a manner similar to the data used in Table 3, as have also the combined yields of straw, and stover. As grain crops were on the land for only seven years, the data are not so abundant as those used in Table 3. The results of the calculations are to be found in Table 4.

This table is susceptible to the same interpretation as is Table 3, altho it includes less data and is not so clearcut and definite. The odds, it may be observed, are much lower than in the previous table. It is significant, however, that the odds are much higher for the yields from the plats receiving the farm manure as a basic treatment than from those to which the minerals were applied.

SUMMARY

Nine crops were grown on field plats treated with graduated quantities of acid phosphate and floats. Acid phosphate was used to make sure that the soil responded to phosphorus. Certain of the plats were given a basic treatment of farm manure and others of nitrate of soda and muriate of potash.

The application of floats to the manure treated plats increased crop production with odds decidedly favorable. While increases were obtained from the use of floats with a basic treatment of minerals instead of manure, they were by no means as significant or as large. Moreover, the crop yields of manure treated plats increased with larger applications of floats. This was not true of the plats receiving nitrate of soda and muriate of potash as a basic treatment. These results may be taken to indicate that the manure contributed markedly to the availability of the floats under the conditions of the experiment.

LITERATURE CITED

1. WAGGAMAN, W. H., WAGNER, C. R., and GARDINER, R. F. Analysis of experimental work with ground raw rock phosphate as a fertilizer. U. S. Dept. Agri. Bul. 699, pp. 119. 1918.
2. BONSTEEL, Jay A., FIPPIN, ELMER O., and CARTER, WM. T., JR. Soil survey of Tompkins County, New York. *In* U. S. Dept. Agr. Field Operations of the Bureau of Soils for 1905, pp. 28, 29. 1906.
3. LYON, T. LYTTLETON, and BIZZELL, JAMES A. Lysimeter experiments, Cornell Univ. Agr. Exp. Sta. Mem. 12, p. 12. 1918.
4. STUDENT. Probable error of the mean. Biometrica, V. 6:1–25. 1908–9

———Tables for estimating the probability that the mean of a unique sample of observations lies between minus and infinity and any given distance of the mean of the population from which the sample is drawn. Biometrica, 11:414-417. 1917.

FLUCTUATING VARIATIONS IN THE SOY BEAN[1]

B. D. Leith[2]

Manufacturers of paint have been interested for several years in experimenting to ascertain to what extent the soy bean oil can be substituted for linseed oil. In 1911, the writer became interested in the problem of oil production, which presented three outstanding features; namely, the percentage of oil in the beans, the drying index of the oil, and the productive power of the strain of beans. The protein content was studied incidentally, later. Naturally some interesting other possibilities had to be dropped in order to follow the three aspects of the problem mentioned above. As high performance was the basis of selection, no attempt was made to carry on inferior strains.

The first five year's work was concerned quite largely with determining the varieties adapted to Wisconsin conditions. From these, selections were made of the strains of beans which gave the highest tests for oil and iodine index Sixty-one variety tests were made, representing 52 different stocks.

In 1914, plant selections were made from two promising strains. Further selections were made the following year. Later several reselections were made, as some of the lines became mottled and showed other evidences of heterozygosity Forty-one different selections were made in 1916 and analyzed for oil and iodine number. It was becoming evident that there was considerable fluctuation from year to year The stocks which showed high oil content and iodine number were selected as mother plants in an attempt to stabilize the high testing strains.

The first two tables show variations in selections from Wis. 32 (S. P. I. No. 30746). Ten selections were made in 1914 from plant No. 7 and were numbered 32–1 to 10 inclusive. Five were made from No. 11 in 1914 and numbered 32–11 to 15 inclusive. The results of the tests on these in 1914, 1915 and 1916 are shown in the following table.

In 1914, the fifteen individual plants selected from Wis. 32 (S. P. I. No. 30746) gave a range from 13.21% to 19.91% in oil content and from 103.7 to 135.4 in iodine number. In 1915, the ten selections from plant 7, gave a variation in oil from 14.84% to 19.51%. The

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iodine number in this selection varies from 125.8 in 1916 to 141.5 in 1915.

TABLE No. I—A. *Variation in percentage of oil of individual plant selections* From Wis. No. 32 (S. P. I. No. 30746)

1912 Oil percent	Test No.	1914 Oil percent	Selection No.		1915 Oil percent	1916 Oil percent
17.28	1	18.03	No. 7	32–1	17.35	16.69
	2	17.52		32–2	17.36	Killed
	3	17.36		32–3	16.17	17.62
	4	15.81		32–4	19.51	18.56
	5	13.21		32–5	17.70	18.41
	6	17.77		32–6	17.39	18.51
	7	19.61		32–7	16.37	17.12
	8	16.75		32–8	14.84	17.71
	9	16.34		32–9	17.03	17.88
	10	18.25		32–10	17.51	17.52
	11	18.05	No. 11	32–11	17.99	18.67
	12	19.56		32–12	17.95	17.96
	13	17.81		32–13	18.72	17.53
	14	19.91		32–14	18.78	17.75
	15	16.21		32–15	18.78	18.09

B. *Variation in Iodine No. of Individual Plant Selections* From Wis. No. 32 (S. P. I. No. 30746)

1912 Iodine No.	Test no.	1914 Iodine no.	Selection no.		1915 Iodine no.	1916 Iodine no.
133.3	1	125.8	No. 7	32–1	138.0	130.8
	2	127.5		32–2	138.5	Killed
	3	122.4		32–3	140.5	132.0
	4	103.7		32–4	136.5	129.92
	5	112.5		32–5	141.5	127.1
	6	122.1		32–6	134.5	129.7
	7	134.4		32–7	136.5	129.5
	8	130.4		32–8	138.5	128.2
	9	125.2		32–9	140.0	125.8
	10	129.1		32–10	134.5	128.4
	11	128.0	No. 11	32–11	135.0	126.0
	12	135.4		32–12	136.0	131.5
	13	133.2		32–13	134.0	124.91
	14	131.3		32–14	133.0	129.7
	15	110.2		32–15	123.0	129.8

Table 2 shows two lines from Wis. 32 (S. P. I. 30746), 32–4, and 32–12 with reselections carried on since 1915.

In 1921 and 1922, no greater percentage of oil was found than in the composite sample in 1912 and 1914. Similar results are shown in the iodine number and protein tests.

Table 3 shows an interesting divergence between the two selections from this line 32–4–1 and 32–12–1.

In four years out of the six year test, the percentage of oil is higher in 32–12–1, ranging from .31% to 1.1% higher than its sister selection 32–4–1. The year 1916 shows about the same percentage of oil in both selections and in 1921, 32–12–1 showed .63% lower oil content. In the tests for protein content, 32–4–1 gave higher re-

sults each year than did 32–12–1, and in the tests for iodine number, 32–12–1 was consistently higher. This evidence seems to show that, in some strains at least, a difference in chemical composition might be expected.

TABLE 2.—*Results of analyses of soy beans selected and reselected from Wis. No. 32 (S. P. I. 30746)*

	Oil percent	Protein percent	Iodine No.
1912 Wis. 32	17.28	——	133.3
1914 Wis. 32	19.61	38.31	134.4
1915 Wis. 32–4	19.51	39.06	136.5
1915 Wis. 32–12	17.95	35.25	136.0
1916 Wis. 32–4	18.56	——	129.9
1916 Wis. 32–4–1	16.51	——	125.0
1916 Wis. 32–12	17.96	——	131.5
1916 Wis. 32–12–1	16.20	——	129.2
1918 Wis. 32–4–1	17.83	38.2	124.1
1918 Wis. 32–12–1	18.14	35.0	129.0
1919 Wis. 32–4–1	17.75	44.5	124.5
1919 Wis. 32–12–1	18.50	42.4	127.6
1920 Wis. 32–4–1	16.90	41.31	131.0
1920 Wis. 32–12–1	18.46	39.48	132.3
1921 Wis. 32–4–1	18.42	38.43	126.83
1921 Wis. 32–12–1	17.79	33.75	128.98
1992 Wis. 32–4–1	17.8	40.02	143.0
1922 Wis. 32–12–1	18.9	39.25	146.0
Averages	18.00	38.84	131.62

TABLE NO. 3.—*Selections from Wis. No. 32, showing divergences of two lines in oil, protein and iodine number*

	Variation in oil		Variation in protein		Variation in iodine Number	
	32–4–1	32–12–1	32–4–1	32–12–1	32–4–1	32–12–1
1916	16.51	16.20	——	——	125.0	129.2
1918	17.83	18.14	38.2	35.0	124.1	129.0
1919	17.75	18.50	44.5	42.4	124.5	127.6
1920	16.90	18.46	41.31	39.48	131.0	132.3
1921	18.42	17.79	38.43	33.75	126.83	128.98
1922	17.8	18.90	40.02	39.25	143.0	146.0
Avg.	17.54	18.00	40.49	37.98	129.07	132.18

Another case of selection and reselection for ten years is given in table 4.

In each case a number following a dash indicates a selection. For example, 33–2–1–1–1 means that from the first selection from this stock 33–2, there were three reselections made. These reselections were made because of evidences of heterozygosity developing in the stock. The fluctuations in oil content the first two years, were from 16.94% to 18.54%. After selection and reselection for high oil in eight subsequent years, the fluctuation from year to year is very similar to that of the first two years. Both selections are somewhat higher than the average in oil content in 1922, but this can be attributed to seasonal conditions.

TABLE 4.—*Showing selections and reselections from soy beans, Wis. 33, Quebec No. 92*

	Oil percent	Protein percent	Iodine No.
1913 Wis. 33	16.94	43.12	130.5
1914 Wis. 33	18.54	43.31	132.1
1915 Wis. 33–2	16.44	40.06	129.0
1916 Wis. 33–2	17.36	——	129.5
1917 Wis. 33–2–1	18.90	37.6	132.0
1918 Wis. 33–2–1	18.05	34.4	124.3
1919 Wis. 33–2–1	17.75	41.7	126.0
1919 Wis. 33–2–1–2	18.61	42.3	126.5
1920 Wis. 33–2–1–2	17.02	39.75	130.3
1920 Wis. 33–2–1–1	17.74	38.56	128.9
1921 Wis. 33–2–1–2	17.0	38.18	126.7
1921 Wis. 33–2–1–1–1	18.29	36.66	130.3
1922 Wis. 33–2–1–1–1	21.1	42.62	134.0
1922 Wis. 33–2–1–2	18.6	42.17	139.0
Averages	18.02	39.97	129.94

The protein content in the tenth year is not quite as high as in the first two years. The iodine number in 1921 is lower than in 1914. In 1922, it is higher, but this again may be attributed to seasonal conditions, as none of the earlier figures for iodine number show gains.

SEASONAL INFLUENCE AS A CAUSE OF VARIATION

A twelve year study of a pure line of Ito San, Wis., Ped. 2 shows wide fluctuations from year to year in oil and protein content and iodine number of the oil.

TABLE No. 5.—*Analyses of Wis. Ped. 2, Ito San soy beans*

	Oil percent	Protein percent	Iodine No.
1911	16.35	40.41	——
1912	17.58	——	126.88
1913	19.08	41.25	124.9
1914	14.1	49.94	133.0
1915	17.28	38.88	131.0
1916	17.15	——	123.3
1917	17.25	41.8	130.4
1918	16.67	40.8	130.4
1919	15.45	45.8	125.3
1920	16.11	40.81	133.6
1921	16.18	37.21	124.0
1922	19.8	39.5	136.0
Averages	16.92	41.64	128.98

Climate undoubtedly is a factor in producing these variations; but probably other local environmental factors such as soil, or cultivation have a part. Then, again, the variety may be so genetically constituted as to react differently to the different factors. Reference to Tables 2 and 4 shows that in the year 1914 there was a high percent of oil in both Wis. 32 and 33, while it was very low in Ped. 2. The protein content and iodine number were very high in Ped. 2 in that year and average in the other two varieties. Tables 3 and 5 make possible a comparison between Ped. 2, 32–4–1 and 32–12–1

from 1916 to 1922; 1919 is evidently a year favorable for high protein production and 1920 and 1922 favorable for high iodine number. Further than this no outstanding features are presented.

DISCUSSION

This experiment was not planned primarily to study fluctuating variations in soy beans, but the chemical data was used in connection with the selection for high production and good quality. As a result, many individuals that would have made an interesting study on the subject of fluctuating variations were dropped because they were low producers. However, as the work dates back to 1911 and many selections and reselections have been made, some of the data which is here submitted is continuous over several years and seems to be a worth while contribution to the somewhat meager data otherwise available.

While the results of the attempts to change the chemical composition of soy beans by selection have been nil, yet heritable differences are evident. In Table 3 there are shown two selections from the same stock which have shown consistent fluctuations in the same direction from year to year in protein content and iodine number of oil and also a close comparison in percentage of oil.

The interesting fact is that in oil and protein content and in iodine number, the fluctuations from year to year have been large, and that only within rather wide limits have they been consistent in a certain direction between varieties in a single year.

The data herewith presented are insufficient to permit the drawing any conclusions. However, that the year 1919 produced high protein beans can be seen by referring to tables 3, 4 and 5 and these same tables show that in 1920 and 1922 the oil from the soy beans possessed a high iodine number. It is very evident that the chemical composition of the soy bean responds to environment, but evidently so many factors are concerned that controlled experiments which will eliminate all but the one in question seem to offer the only method of solution of the problems involved.

METHODS NOW IN USE IN CEREAL BREEDING AND TESTING AT THE CORNELL AGRICULTURAL EXPERIMENT STATION[1]

(IN COOPERATION WITH THE UNITED STATES DEPARTMENT OF AGRICULTURE)

H. H. Love and W. T. Craig[2]

In 1918, a paper was published in this Journal[3] by the authors describing the methods used in cereal breeding and testing at the Cornell Agricultural Experiment Station. Since there are so many investigators conducting work along these same lines there is considerable interest manifested in the methods used by various stations. Every one is looking for opportunities for improvement and for methods that will save labor and expense in such experiments. For this reason, this revision of our former paper is presented at this time.

At the Cornell Station, the majority of the yield tests are conducted on the rod-row basis; since, with soil that is highly variable, it is not possible to determine yields accurately by the use of large plats unless they are replicated several times. Another point is that if plats are used, the number of varieties or strains to be tested is necessarily limited; since with a number of replications of plats the area of land needed increases very rapidly. On the other hand, those interested in improvement work must have some measure of the value of strains before enough seed is available to conduct the tests in plats.

HOW SELECTIONS ARE MADE

The methods to be outlined here are used both for the selections made from commercial varieties and for the selections made from hybrids. The methods used in making selections were outlined in the earlier paper; nevertheless, it will be worth while to review briefly the methods used. Selections have been made from various fields which are found in different parts of the state. In all cases heads are selected rather than plants, since it is difficult to separate plants as grown in the field as two or more may be pulled up together. Sometimes, when selections are to be made from a certain variety a large

[1]Paper No. 118, Department of Plant Breeding, Cornell University, Ithaca, New York. Received for publication December 18, 1923.

[2]Professor of Plant Breeding and Agent in Cereal Investigations in cooperation with U. S. Department of Agriculture, respectively.

[3]H. H. Love and W. T. Craig. Methods used and results obtained in cereal investigations at the Cornell Station. *In* Jour. Amer. Soc. Agron., 10: 145-157. 1918.

number of individual seed of this variety are planted, giving them space enough in the planting so that the individual plants may be studied and selected. These plants or heads, regardless of the method used in making the selections, are kept separate for sowing. No elaborate data or records are kept of the individuals at first. Experience has shown that, since there will be considerable elimination at the end of the first year, it is better not to spend too much time on these individuals in the beginning. Later, more detailed records of those that remain in the test are desirable.

The plan used in making selections from hybrids is to select plants usually rather than heads; that is, when certain varieties have been crossed for the purpose of obtaining something of commercial value, the plants are selected from the second generation in some cases and from the third generation in others. In sowing the seed preparatory to making such selections, the rows are a foot apart and the seed spaced two to three inches apart in the row. Whenever crosses have been made between varieties of which it is known definitely how the characters are inherited, it is possible many times to make selections from the second generation. It is recognized, to be sure, that in some instances plants will be selected which are heterozygous and will segregate in the succeeding generation. Even so, these plants are included in the selections made. In dealing with such hybrid families it is planned to select large enough numbers so that one may obtain the type desired in the homozygous families without having to continue further with the heterozygous types. At the same time, if certain selections which prove themselves to be heterozygous exhibit a number of very promising plants, such plants are selected from these families and continued in the test the following year.

METHODS OF TESTING

Whether selections have been made from varieties or from hybrids, the plan for sowing these is to sow them in rows from three to five feet long, depending upon the amount of seed available. If heads have been selected, they are sown in rows about three feet long and these rows are a foot apart, as, in fact, all of the rows in the nursery are. If plants have been selected, they are sown in rows usually four to five feet in length. The seed is not spaced but is drilled in evenly by hand. The check rows are sown at the same rate as the selections. This rate, of course, varies according to the amount of seed available. In each case, a check row is sown every tenth row. The seed for these check rows is chosen from the best strain or variety that has been obtained, as determined from its behavior over a period of

years. The best strain or variety is used because its yield and other qualities are known and comparisons may be made directly in the field between the new lines under test and the check variety. Selection from these head—or plant—rows is based largely upon appearance in comparison with the check. In making these selections attention is given to such characters as winter hardiness in the case of wheat, stiff straw, type, maturity, freedom from disease, and the like. Later, the grain is examined for color, quality, and other characters that may make a strain desirable. The yield of these short rows is not taken, since it is obvious that the results of such a test would give no very definite information as to the yielding capacity of these strains.

After the various studies have been made the selections are designated for continuing the work another season. In all cases, it is planned wherever possible to obtain enough seed to sow at least two rod-rows. The two rows of each sort are not sown adjacent, but it is planned to sow a single row from each strain continued in the test and then when the entire series is sown to repeat the process without changing the order of the varieties. In arranging the plan of planting for this second and succeeding years, the different strains are grouped together in accordance with their morphological characters. Where the time of maturity has been shown to be different the early, mid season, and late strains are grouped, so that there will not be any competition effect due to early and late strains growing side by side. Groupings are also arranged in accordance with the other characters; for example, bearded or beardless, color of chaff, and color of kernel in wheat, and so on, in order to make a comparison between the same or similar types by having them all grown close together. In this second year test, a check is sown every fifth row. During the growing season the agronomic notes which are usually considered necessary are taken. The kinds of notes will depend, of course, upon the crop and what is under observation for the particular crop.

The yields from this second year's test are determined; and, while it is realized that such yields are not as reliable as those made from a larger number of tests, selections may be made on the yield basis by comparing them with the check yields and being rather liberal in selecting those types that show up fairly well in comparison with the checks. Any strain that is considerably below the check yields is eliminated at once. Those that are superior or about equal to the check are continued for further testing. It is recognized that by this method occasionally a good sort may be discarded early in the

test. At the same time, it is thought that it is much better to eliminate in this way, making it possible to bring in new selections much more frequently and thereby in a few years to deal with much larger numbers than would be possible if all the selections which have been made were tested a longer period of years.

The strains that have shown promise in this second year's test are continued for the third year and placed into a five rod-row test. These rows are handled the same as in the second year's test; that is, a check row is sown every fifth row and a single row of each strain is sown until all of the sorts appear once, and then the entire series is repeated four times. The field work and the technique of comparisons, etc., is, of course, much the same as in the second year's test.

The strains that are unusually promising from this five-row series are immediately placed in a ten-row series the following year. Those that are of doubtful value are kept in the five-row series; while those that are apparently of little value are discarded at once. In the ten rod-row series, each sort occurs ten times with a check every fifth row and the series arranged as described for the previous tests.

After a new selection has proved its value in the ten rod-row series and seems to give promise of taking its place in commercial growing, it is placed in what is termed an "advanced test". This advanced test is arranged in the following manner: three rod rows of each strain are sown in adjacent rows and each strain tested is replicated nine times, thus giving ten blocks of three rows each. In arranging this series, three rows of the check variety are first sown, then three rows of variety A, three rows of variety B, and three rows of the check. This plan is continued until each strain is included, then the series is replicated. Thus, each strain under test grows next to a check. The advantage of this method is that it gives a somewhat better measure as to stiffness of straw and some general characters than does the series where each variety occurs as a single row. At the same time, since every strain is growing next to a check and the check has proved qualities, it is comparatively easy to draw conclusions regarding the behavior of the new strain. The method of obtaining yields from this advanced test is to thresh each row separately and weigh the grain separately. In using this method, if it is felt that competition plays a part the results from the middle rows only may be used for this yield determination. Since in the strain tests conducted by those interested in improvement, the strains included are apt to be very much alike so far as their general growth and behavior is concerned, so that there will be little effect from competition. Competition has not been shown to have any

effect in these experiments. In this advanced test, in addition to the new strains, the better commercial varieties or the varieties that the farmers are apt to be growing are included, in order to make a direct comparison between these and the new selections.

Drill Plats

From the advanced test the promising strains as well as some of the better commercial varieties are selected to grow in drill plats. These drill plats are sown by means of a drill. The one that is now used is an eleven-hoe drill and the two outside hoes are closed so that nine drills are sown for each strain. These plats are 100 feet long. This length is used because all of the land operated by the Department of Plant Breeding is laid off in tiers 100 feet in width. By closing the outside hoe and allowing the wheel to follow the wheel track upon drilling the next plat, plenty of space is allowed between plats to accommodate the binder at harvest time so that the opportunity for mechanical mixture is largely eliminated. These drill plats are always sown in duplicate, and if land is available, in triplicate. It is desirable to have them replicated even more times. A check plat is sown as every fifth one, altho if land is available it is more desirable to sow it as every third one. Little dependence is placed upon the yields of these plats, particularly if they are only sown in duplicate, as accurate yields, with most types of soil, cannot be determined in this way. These plats are used mainly for the multiplication of seed and to permit a comparison of the various sorts under field conditions. The new strains that have been proved to be of sufficient value to be distributed for commercial growing are multiplied in multiplication plats. These plats are carefully rogued to insure seed of a high degree of purity.

Seed Rows

In handling this kind of work, it is necessary that a large number of different strains be handled the same year. With the plan of growing rows only a foot apart, it is possible for an occasional head from one row to get mixed in with another. This is particularly true where many thousands of rows are being handled and must of necessity be harvested rather rapidly. Any slight mixture that does occur in this way will not, of course, affect the yields the year of the mixing. If allowed to continue in the seed, however, such mixtures may multiply and eventually affect the yields. In order to eliminate such possibilities, the plan of sowing seed rows has been adopted. It is not possible nor wise to have seed rows of every strain tested.

The plan that is followed is that when new strains are brought into the test no seed rows will be sown from these until after they have survived the elimination of the five rod-row series. In other words, when a sort has proved its value sufficiently to be placed in the ten-row series, seed rows are then sown. To be sure, some slight mixture may occur in the sort so that when it reaches the ten-row series it will contain an occasional mixture, altho it is planned to eliminate these by rogueing one series in the two and five-row lots each year and saving seed only from these rogued rows. The plan of sowing the seed rows is to sow two rows of each sort in adjacent rows, leaving vacant a row on each side or between one strain and the ones adjacent. This makes it possible to get around the seed rows for rogueing and also greatly reduces the possibility of heads falling from one strain over to another. These seed rows are harvested with special care and the greatest of care is used in threshing and other operations.

A diagram illustrating the plan used for the rod rows and advanced test is shown in Figure 1.

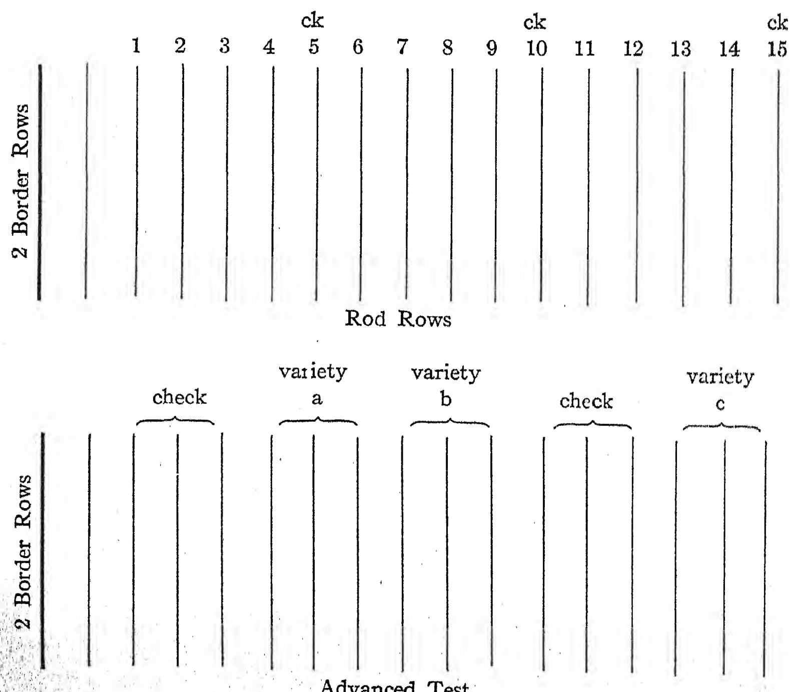

Figure 1. Scheme for sowing the rod rows and advanced test.

These different series of tests thru which a strain is carried may be summed up in the following manner:

First year—Selection from variety or hybrid tested in three to five foot rows, check every tenth row.

Second year—Rod rows duplicated, check every fifth.

Third year—Rod rows replicated four times, check every fifth.

Fourth and following years—Rod rows replicated nine times, check every fifth. Seed rows sown.

Advanced test—Rod rows three in a block, replicated nine times, check every third block.

Drill plats—Replicated as many times as land permits, check every fifth or oftener.

Increase plats—For multiplication of seed.

Sowing

It probably is worth while to mention some of the details in connection with planting and harvesting rod rows on a large scale. The planting is done by hand and, in fact, can be done by hand better than by the use of any machinery now available. Before planting time the seed is weighed out in separate envelopes and the envelopes are given a row number and checked with the plan of planting, and then arranged in groups of ten. The weight of seed is determined by the rate of seeding commonly in use. At Cornell, the rate used is two and a half bushels for oats, one and a half for wheat, two for barley, and one and a half for rye.

In order to mark out the rows quickly the machine illustrated in figure 2 is the one which is now in use. Ordinary four-inch cultivator shovels are used and the machine is arranged with a lift for convenience in turning, etc. The shovels are fastened on shanks which are one foot apart. With this machine, it is possible to mark and open the rows at the same time. If the ground is not in the best of condition it may be necessary to go thru the rows twice but where the soil is well prepared, once is enough, particularly for spring sowing. In using a machine like this, it is well not to mark out too far ahead of the men who are doing the sowing since the furrows may dry out and delay germination. This matter would depend entirely upon local conditions. It is possible, however, to open across a range. As the ranges used at the Cornell Station are 100 feet wide, the rows are opened across the entire range. It has been found by experience that this can be done with safety. A few hours work will mark enough rows for a day's sowing for three men. A word may be said regarding the speed of seeding rows by

this method. After the rows are marked out, five men will sow and cover about 2000 rows a day. An experienced man can sow 80 to 100 rows an hour. This does not include covering.

FIGURE 2—Showing the especially constructed horse-drawn combined row marker and furrow opener.

After the rows are opened the field is laid off by means of stakes and a line, giving just the proper length of the rows and the borders or paths between the series. With wheat and rye sixteen feet rows are seeded and with oats and barley fifteen feet. Formerly, the length of row was modified for the different crops in order to make the calculation of yield which is determined in grams into bushels per acre; but by means of proper methods for calculation this is not so very important and, as it is better to have a row of convenient length for handling, the lengths given above have been adopted. Between the different sections there is a two-foot border or path.

After the furrows are opened and the lines stretched, the envelopes containing the seed are laid out in order, placing a stake every tenth row, and the seeding and covering is done by hand. These methods are illustrated by Figures 3 and 4.

Harvesting And Storing

The rows are harvested separately, three men working together. Two men do the cutting and one man looks after the binding and tagging. Such a group can harvest from 500 to 800 rows a day.

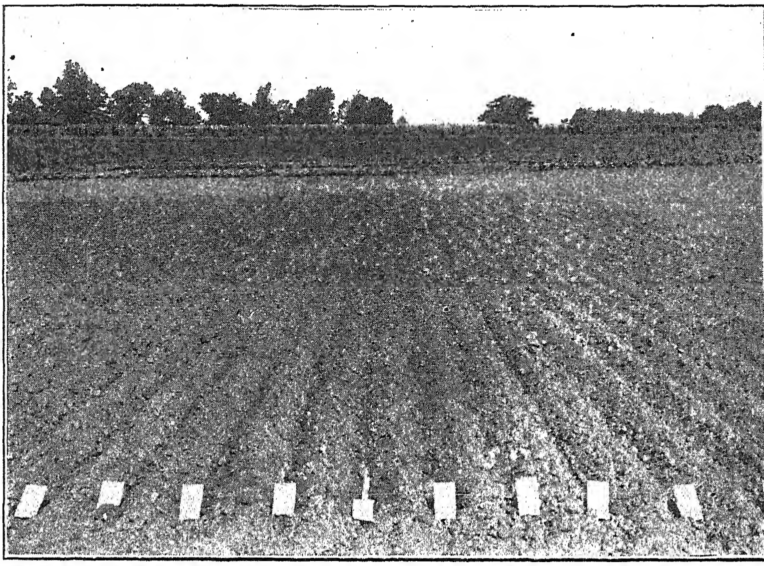

FIGURE 3—Showing the opened rows and the seed laid out ready for sowing.

FIGURE 4—Laying out seed and sowing rod rows.

The entire row is harvested. Formerly, longer rows were sown and the ends cut off to eliminate border effect, etc. Careful observation has shown that this is not necessary and does not pay for the extra labor, especially since the rows are replicated a large number of times. With the narrow paths between the series the border effect under conditions at Ithaca is very slight. The bundle is bound at the

bottom with ordinary twine and around the top with wired tags which have previously been numbered with the row number corresponding with the row. These tags have been especially wired with double twelve-inch wires so that they are long enough to reach around

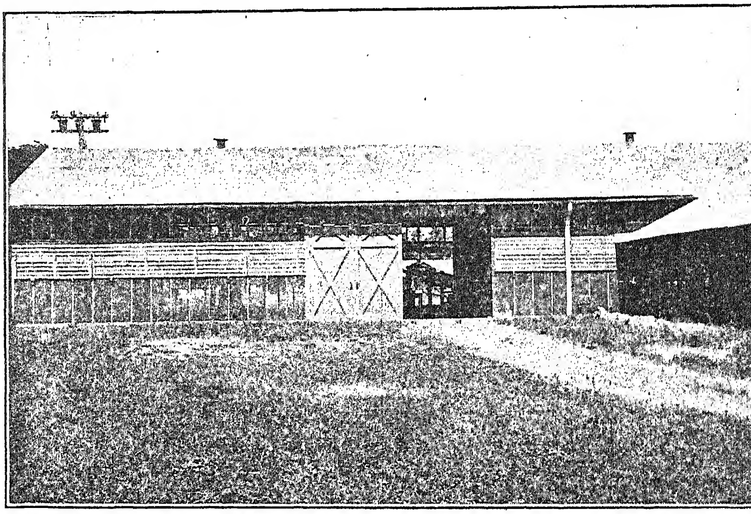

FIGURE 5—Showing part of the new storage house and threshing shed.

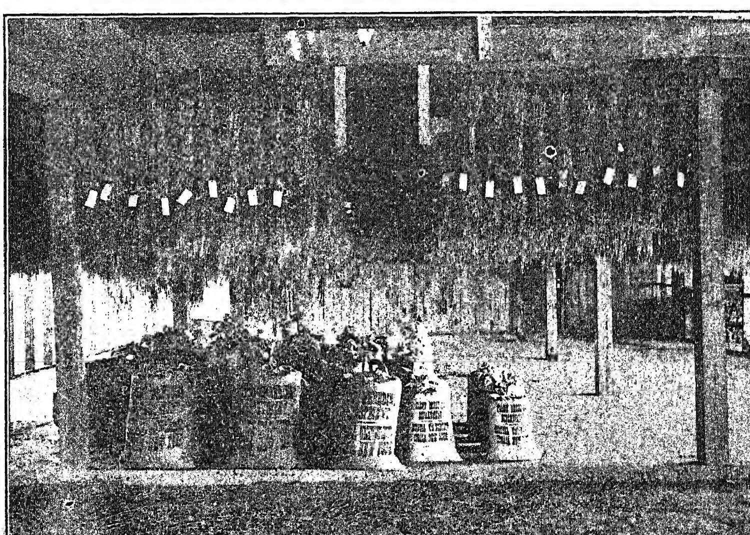

FIGURE 6—Showing the bundles of grain hanging in the threshing shed drying, ready for threshing.

the average bundles grown in our nursery. These bundles are bunched in groups of ten and are immediately taken into the storage shed and hung heads down as indicated in the accompanying illustrations.

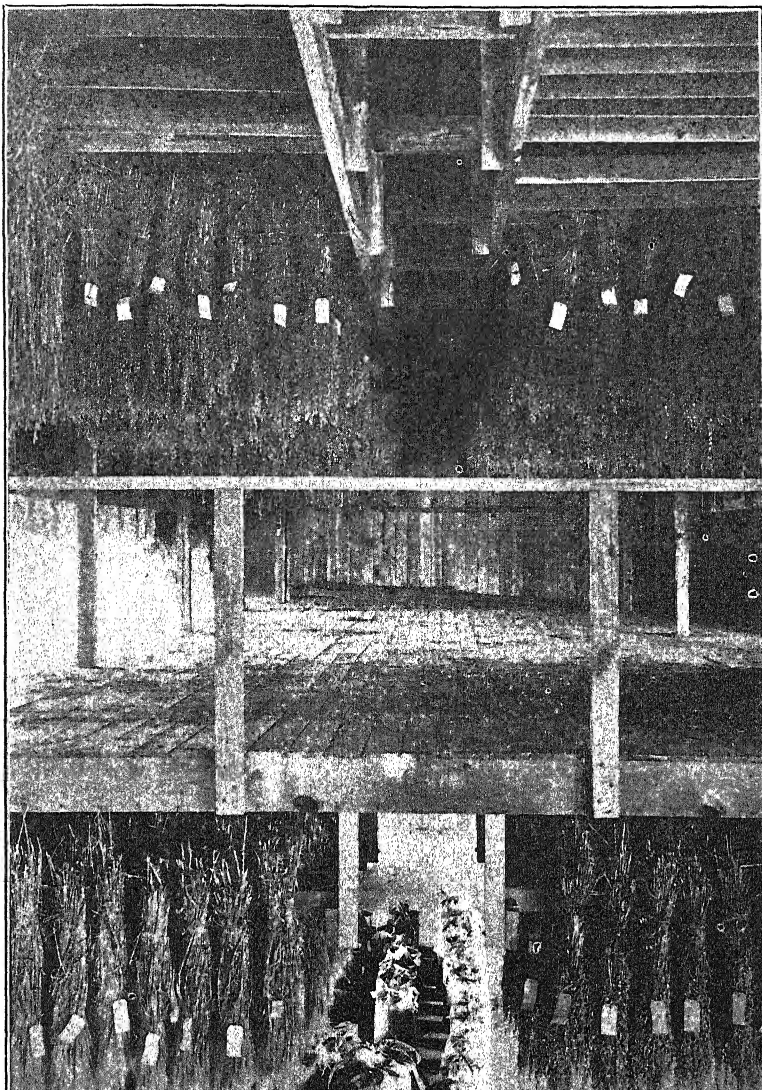

FIGURE 7—A view of the drying shed showing grain hanging on the upper and lower decks.

This method of storing the harvested grain has been found so satisfactory that a new storage, drying, and threshing house has been built for this purpose. The building is equipped with three large compartments for artificial drying by the use of steam, one room for threshing and two large floors for the hanging of such material as the bundles of small grain and the like. Figure 5 shows a part of this building. The method of hanging is shown in Figures 6 and 7.

The fact that the grain is taken in immediately after being cut and hung heads down eliminates a great deal of mixture that might occur upon handling many varieties together. If any kernels are mixed in the different bundles due to hauling in from the field, the shaking while hanging these on the crosspieces will eliminate practically all of them and as the grain dries any loose kernels so mixed in will rattle loose. The crosspieces shown in the illustration are so arranged that ten bundles will hang on each side of the crosspiece. These bundles are hung in exactly the same order in the drying shed in which they occur in the field, so that at any time it is possible to find the bundle belonging to a certain row. This is very important at threshing time since by passing down and back in one aisle one workman collects all the bundles belonging to a variety.

Threshing And Storing The Grain

The threshing is done by means of a specially constructed machine which is illustrated in Figure 8. When threshing, the crop from the

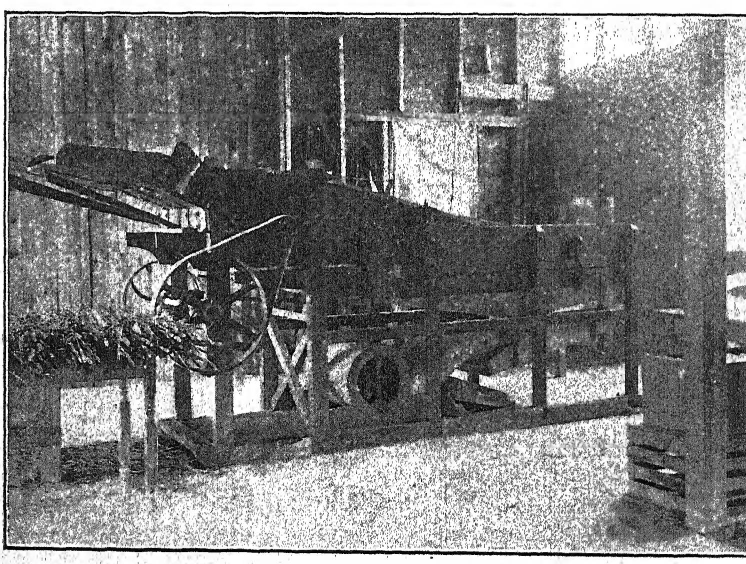

Figure 8—A view of the especially constructed threshing machine used in threshing rod rows and small plats.

five or ten-row lots or other groupings (all the rows of a variety) are collected together and the several bundles all belonging to the same variety are threshed one following the other. In this way it is not necessary to clean the machine thoroly between each bundle, as it is so constructed that the few kernels that remain will not affect the yield. After the last bundle of a variety is threshed, the machine is brushed out thoroly before another variety is run thru. This threshing machine is so constructed that nearly all of the inside is visible; so that the mixing due to grain remaining in the machine is reduced to a minimum. Three men run the machine and can thresh on an average about 700 rows a day.

The grain from the rod rows is kept in twleve-pound paper bags and is weighed in these bags. A type of bag may be obtained which runs quite uniform in weight. The weights are all taken in grams and the yield per acre calculated from these weights.

Calculation And Interpretation Of Yields

After the yields have been determined for the individual rows, the average yields together with their probable errors are calculated. There are two ways of determining whether a variety is significantly a good or poor yielder. In both ways the comparison is made with the check. The data shown in Table 1 may be used to illustrate the method.

The method for calculating the gain or loss is done in the following manner. The average yield for each strain is determined and its probable error calculated by means of Bessel's formula. The yield for the average of each set of ten check rows (five in the case of the five-row series) is determined and the probable errors for these averages calculated. These probable errors are then calculated as percentages of the mean or average. The average probable error for all the checks is determined by averaging these percentages. This probable error, which is expressed as a percentage, is then applied to the theoretical checks. These theoretical checks are determined in the usual way by grading the soil between the checks; that is, if the average yield of one check is 50 bushels and the next one beyond is 55, the supposition is that there is a regular increase in productivity from the one to the other. The theoretical checks between these two would then be assumed to be 51, 52, 53, and 54. That is, the difference between the checks which is 5 bushels in this case is divided by 5 and the quotient (1) added to the lower check. Of course, if the change were in the negative direction, the quotient would be subtracted.

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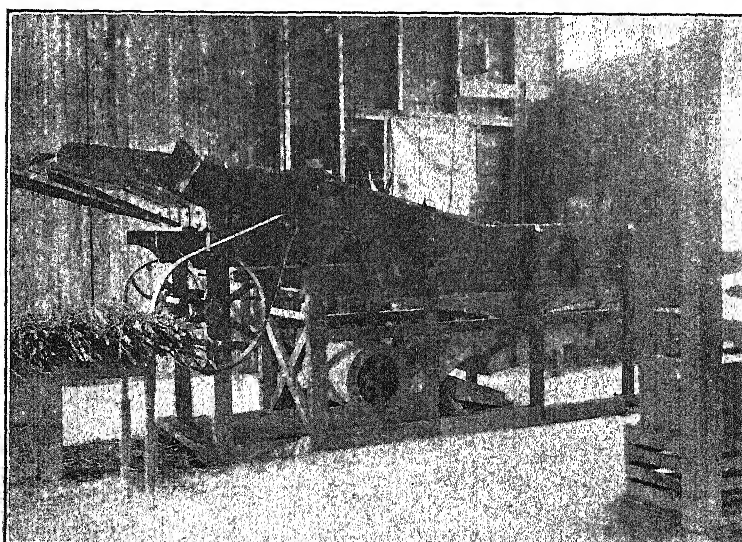

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TABLE 1.—*Yields of four strains of wheat and the adjacent check rows. Ten replications.*

Variety	Yield of the ten replications in bushels per acre										Ave. bu. per acre	Theoretical check	Gain or loss
Check	25.9	19.5	28.0	19.9	20.0	21.0	31.3	18.2	25.4	35.0	24.4		
Fulcaster	25.9	23.0	27.3	28.2	35.2	27.2	37.2	22.0	26.0	38.8	29.1±1.26	23.7±1.11	5.4±1.68
Selection 133–115	31.1	24.5	30.2	29.1	35.8	30.0	43.1	28.0	29.7	46.3	32.8±1.47	23.1±1.09	9.7±1.83
" 133–114	20.2	15.5	27.3	26.1	35.5	36.3	30.4	25.7	20.0	33.7	27.1±1.50	22.4±1.05	4.7±1.83
" 133–229	29.3	21.3	30.7	30.2	36.4	37.4	35.6	27.8	24.7	36.3	31.0±1.16	21.8±1.02	9.2±1.54
Check	19.0	20.4	18.1	24.3	24.6	18.9	23.6	18.8	15.4	28.3	21.1		

Applying this to the data in Table 1, the check yields are 24.4 and 21.1 bushels, and the theoretical checks are as indicated in the Table. The average probable error for the checks for this particular year is 4.7 percent. The theoretical checks are then multiplied by this constant and the probable errors of the theoretical checks are determined in bushels per acre. The theoretical check yields are then subtracted from the actual yields of the strains under test. This gives the results in the column headed "gain or loss." Since both the actual yields and theoretical checks are affected by a probable error, the error for the gain or loss is obtained by the usual formula,

$$\text{P. E. Difference} = \sqrt{E_1^2 + E_2^2}$$

In interpreting these results, then, no gain or loss is thought to be significant unless it is at least three times its probable error. In selecting strains to be continued in the test, however, some whose gain is not three times the probable error are continued since it is recognized that the results of one year are not conclusive. Those that are inferior to the check, on the other hand, are rapidly eliminated. When a strain has been in the tests for several years, then to be considered significant it must, as stated above, be three times its probable error.

There may be some objection to this method on the grounds that it is not correct to grade the soil from check to check and that it is not proper to average the probable errors for all the checks. In answering the latter objection first, it seems that this is much more accurate than not to consider the probable errors at all and that this does not seem to introduce any large errors.

Regarding the objection that it is not correct to grade the soil from check to check, it may be stated that this matter has been studied statistically and the complete results will appear in another paper. It is sufficient to state here that for three years 600 rows of the same variety have been sown and treated in the following manner. Every fifth row is assumed as a check and the intervening rows are compared with the checks in the same manner as indicated above, that is, by grading the soil from check to check. The probable errors are calculated in the same manner, as is also the gain or loss over the check. If errors were introduced by this method of grading, it is to be expected that some gains or losses will be found that will exceed the probable errors considerably. Such has not been found to be the case, and it is concluded that the above method is sufficiently correct.

Another very useful method which may be used in determining the

significance of a gain is that published by Student.[4] Bessel's formula, which has been used for the above method, does not eliminate systematic errors due to great differences in the fertility of the soil, etc., while Student's method, since it deals with paired results, tends to eliminate systematic errors. To apply this method to the results in Table 1, it is necessary to determine the theoretical checks between the individual checks rather than the average of the ten checks. Then the yield of the theoretical check is subtracted from the yield of each row of the strain under test and the difference obtained. The average of these differences is then obtained, and is the gain or loss over the check. From this mean the standard deviation and probability that the difference is not due to chance alone may be obtained, as given by Student and outlined by one of the present writers in volume 15, page 217–224, of this JOURNAL. It does not seem necessary to give the details here, but the writers have found this a very useful method.

Number Of Rows Needed

Regarding the number of rows needed for tests of this sort, it may be said that it is believed that for conditions at Ithaca at least ten rows should be grown for the final eliminations and then for greater accuracy such a series as the advanced test should be used. The probable error for different numbers of rows has been worked out and the results for three years show that the probable error for five rod rows is about 38 percent higher than for ten and for three rows it is about 90 percent higher. When fifteen rows are used instead of ten, there is a decrease of about 17 percent. Owing to these results and other considerations, it has been decided to use ten rows as the regular number for final elimination.

METHODS USED IN HYBRIDIZATION

Experience has shown that, so far as the conditions at Ithaca are concerned, it is better to plan to make the crosses of the small grains in the greenhouse rather than in the field. One advantage of importance, not only for conditions at Ithaca but probably for many other places, is that the plants are blooming usually in April and the work may be done before the busier time in the summer when there are so many field notes and other matters which must be attended to just before harvest. Another important consideration is that usually in the greenhouse pollen may be collected for a longer period of time during the day than can be done in the field. A further point is that the flowers suffer from injury less in the greenhouse than in the field.

[4]Student. The probable error of a mean. Biometrika, Vol. 6, pp. 1–.

In the field, during a dry season, the flowers after emasculation wither considerably and often the tender floral parts are exposed to the heat of the sun so that many of them die.

In preparation of the plants that are to be used for hybridization several seed are sown in five-inch pots and after coming up these are thinned to one or two plants. It is better to have only one plant in a pot if this is possible. Where seed of known germination is used, usually it is not necessary to plant any extra seed. It is also advisable to make at least two plantings in order that the different varieties to be crossed will bloom together. This may not be necessary if the maturity of each variety is known. Nevertheless, it is convenient in such cases, since if one fails to obtain the desired cross in the first attempt, there may be plants still blooming, furnishing a second opportunity. It may be pointed out that growing the plants in pots makes it much easier to handle the plants at the time the crossing is to be done, since it is possible to put the pots in a convenient place so that the worker may be comfortably situated while making the delicate emasculations and pollinations.

The plan usually followed in making the crosses is to use only part of the flowers on a plant, thus in each case leaving some flowers to develop self-fertilized seed. These seeds may then be used for growing plants to represent the female parent. In the case of oats, usually a few flowers on a spikelet are chosen for emasculation; and, in the case of wheat, it is better to use all the flowers on a head providing there are two heads on the plant used, if not, the upper florets should be the ones emasculated, otherwise, there is danger if the lower ones should be the ones emasculated of pollen escaping from the upper ones and pollinating the lower emasculated florets. It is desirable to cover the heads with glacine bags, particularly in the case of wheat. In each case the plant from which pollen is taken is so labelled that some seed may be taken from it to represent the male parent of the cross.

It has been found of advantage to grow the first generation plants in the greenhouse, since they can be more readily protected and given the best possible conditions.

In all cases where genetic studies are planned, sample heads and grains of the parents and first generation hybrids are saved. These are found very useful in making later comparisons.

The second and succeeding generations are usually grown in the field, planting the seed in five-foot rows and spacing the kernels about two inches apart in the row. These short rows are used in order to be able to reach in from either side to study a plant during

the growing season without stepping into the bed or otherwise disturbing growing conditions.

The plan for labelling, while not new, may be of interest to beginners. It may be said in passing that there are other systems which may suit the individual worker better than the one here described; nevertheless, this has been found satisfactory for small grain work. Each hybrid is given a series number; for example, if Junior No. 6 wheat be crossed with Forward, this may be given series number 1. Whenever the same two plants have been used as the female and male and several seed are obtained, these different seed and the plants developed from them are numbered as follows: 1a1, 1a2, 1a3, etc. If the same varieties but different plants have been used, the same series number can be kept but the seed obtained by using a different set of plants should be numbered 1b1, 1b2, 1b3, and so on. The plants from the second generation when given a number are numbered as follows: 1a1–1, 1a1–2, 1a1–3, and so on. Plants that are selected from the second generation to grow a third are numbered in the following manner: 1a1–1–1, and so on. For convenience, the parent types are designated by X and Y rather than by the conventional signs for female and male. This is done since, with help at harvest time, there is less confusion occasioned by using the labels X and Y than with the conventional signs; this, of course, with the unskilled worker. In our system, then, 1X and 1Y designates the female and male parent for series number 1. This general scheme is one developed by Dr. H. J. Webber, with certain modifications of our own. So far as the labelling of the parent types is concerned this may seem to be a needless change; nevertheless, it is a plan that works well and for that reason is outlined here.

At the time of sowing the seed from the first generation hybrids, it is desirable to keep the seed from each first generation plant separate. No attempt is made to keep the seed from the individual heads separate in sowing. There are times, however, when the characters represented by the different parents are such that one can be sure that the F_1 plants are hybrids and at such times it may be found convenient to plant all the seed from the different plants together.

In our studies it has not been found that any differences have come from reciprocal hybrids. While our studies have not been exhaustive, they have extended over several hundred hybrids of small grains and so far no such differences have been found. In the case of some species crosses there may be some difference in the amount of sterility in reciprocal crosses. This remains yet to be proved.

At the time of harvesting the second generation plants, the follow-

ing plan is used for taking care of the material. This plan is also workable for any other material of a similar nature. The plants are pulled and a rather large number are saved for seed plants for further use. The heads from these plants are cut and those from each plant put in a separate envelope. From the remainder of the plants single heads are taken for the study of the various head and grain characters. In order to save storage space a number of these heads are put in the same envelope. Wherever plant characters are being observed the sorting is usually made in the field before the samples are taken as above indicated, and then each group of plants labelled according to the plant characters under consideration. When growing a third generation from seed of the F_2 plants, if it is possible, a certain amount of seed is held in reserve for making further studies that may occur as a result of the third generation behavior.

THE TEXAS STATION PLAN OF COOPERATIVE DISTRIBUTION OF PEDIGREED COTTON SEED[1]

G. N. STROMAN AND D. T. KILLOUGH[2]

The Texas Agricultural Experiment Station has found after repeated trials that small sample distributions of crop varieties which have been developed by its plant breeders has not been satisfactory. This is because of the liability to loss of the variety due to the lack of understanding by farmers of proper methods of keeping the variety pure, as well as effective means of increasing and distributing the seed commercially.

Accordingly, a smaller number of distributions with larger amounts of seed were tried, and Sudan grass, Spur feterita, and others of the grain sorghums have been distributed in this way with fair success.

On the development of a variety of cotton, however, it was found more practicable to group the distribution into centers, organizing each center for cooperative effort where the "one variety of cotton for a community" idea could be successfully carried out.

It is desired in this article to present briefly the method used by the Texas Station in the distribution of a strain of pedigreed seed, developed by the Station, through a cooperative organization of farmers.

The Texas Station has thirteen substations, where plant breeding is carried on under the supervision of specalists of the Main Station

[1]Contribution from the Division of Agronomy, Texas Agricultural Experiment Station, College Station Texas. Received for publication December 23, 1923.
[2]Cotton Breeder and Superintendent of Main Station Farm, respectively.

and occasionally plant varieties are developed at each substation. The particular instance described in this article is the case of Belton cotton which was originated and developed at the substation at Temple. Belton has been one of the leading varieties for the past several years in the black land section of Central Texas and seems to be growing in favor as its behavior becomes better known.

Through the activities of the Extension Service of the A. & M. College of Texas and the Smith-Hughes vocational instructors at Granger, Williamson County, an organization of farmers had been perfected to foster the "one variety of cotton for a community" idea, and when the association, later known as the Williamson County Belton Cotton-Growers Association, was ready to function, a study was made of the results secured from the cotton variety tests conducted by the Texas Station and the members decided to grow Belton cotton under the supervision of the Station and in accordance with the following contract.

"In this memorandum of agreement between the Texas Agricultural Experiment Station as party of the first part and Mr. Willoby Turner, Agent of the Williamson County Belton Cotton Seed Growers Association, as party of the second part, the parties undersigned do agree as follows:

I

"The party of the first part agrees to sell to the party of the second part twenty-five (25) bushels of Belton cotton seed at $2.25 per bushel for the purpose of growing cotton seed for sale to the members of the Williamson County Belton Cotton Seed Growers Association.

II

"The party of the second part agrees to plant the aforesaid seed in the spring of 1922 upon land which shall not be less than two hundred (200) yards distant from any other growing crop of cotton and to cultivate same to the best of his ability to produce a good and well developed crop of cotton.

III

"The party of the second part further agrees that he will use every possible precaution to prevent the contamination of these seed by admixture of seed of other varieties.

IV

"Realizing the necessity of constant vigilance in maintaining the purity of a strain of cotton, the party of the second part agrees to have this cotton carefully rogued throughout the growing and harvesting season whenever any off-plants appear and realizing that off-type plants are sources of contamination by the transfer of their pollen to other plants, by means of insects, the party of the second part further agrees to use every endeavor to remove such plants before they have bloomed.

V

"The party of the second part further agrees that he will have this cotton ginned on a gin which has been thoroughly cleaned previous to the ginning of same.

VI

"The party of the second part further agrees to sell these seed for not more than \$2.00 per bushel, and that in the sale of these seed, the members of the Williamson County Belton Cotton Seed Association shall have preference after satisfying the agreement set forth in article 7.

VII

"The party of the second part further agrees to give the party of the first part an option on fifty (50) bushels of cotton seed produced by him from the seed covered by this agreement at \$2.00 per bushel, which option shall hold until January 1, 1923.

VIII

"The obligation of the party of the second part under this contract shall terminate June 15, 1923.

Signed on the ———day of———————————by

Party of the first part———————————————

Director, Texas Agricultural Experiment Station.

Party of the second part———————————————

Agent, Williamson County Cotton Seed Growers Association."

The original contract was for one year, but it has been renewed regularly. Mr. Turner, the leader, formed this association, with his neighbors as fellow members who have bought his seed the next year at a price of \$2.00 per bushel.

The success of the plan depends largely upon the individual who is selected by the members of the association as their agent and leader. His initiative, foresight, and care in maintaining the purity of the seed, and his ability to perfect a selling organization for the disposal of the seed are essential considerations which must not be overlooked. The Station has no part whatever in the selling of the seed raised by the Association.

The cotton breeders of the experiment station have made inspections of the fields of Belton cotton each year it has been grown. During 1923, each farmer in the organization was growing some Belton cotton in isolated fields. This will provide a source for distribution and sale to farmers who might be interested in growing the cotton in 1924. Several tours of the fields of Belton cotton were made and instructions were given in the method of rogueing for off-type plants that might appear. Two such tours were made each year, one before blooming and one after the bolls had opened.

A problem which confronted the growers of the Association was the ginning of the cotton in such a way as to insure the purity of the strain. This was simplified by the hearty cooperation of one of the ginners at Granger, who built a special cotton house for the exclusive use of the members of the Association. In this house, each farmer had a cotton stall which had a capacity of ten bales each, where

he could store his cotton as it was picked. When the Association accumulated a sufficient number of bales, the gin was thoroughly cleaned out and all of the Belton cotton then in storage was ginned without danger of mixture with other varieties.

Under field conditions the Belton cotton showed its breeding so well and gave such good results that all of the members of the Association are now well pleased and it is anticipated that in another year the greater portion of the entire cotton acreage adjacent to Granger will be planted to this variety.

The Association plans in another year to employ a cotton breeder and to work as a corporation. Accordingly, this leaves the Station within another year free to start a new center in another community at a considerable distance from Granger and adjacent to its substation at Temple, Bell County, and to develop the plan along similar lines. The Station does not intend to let one association monopolize all of the seed from this or any other substation where breeding work is conducted.

This plan has actually worked at Granger, Texas. The 25 bushels of seed which the Station furnished to the leader of this Association for his 1922 crop produced enough seed for the other members to grow approximately 500 acres of this cotton in 1923. Consequently, from this original 25 bushels of seed furnished by the Station, the Association has 6,313 bushels of pure pedigreed seed for sale to other farmers for their 1924 crop. Thus it can be seen that a pure seed center, established for Belton cotton, has been successful and in operation according to the above described cooperative plan of distribution.

NITRIFICATION EXPERIMENTS ON SOILS OF THE RED PRAIRIES[1]

Henry F. Murphy[2]

INTRODUCTION

Studies concerning nitrification are very important because they are concerned with an element that is likely to be deficient in a large number of soils and one which has such a large influence on the development of plants. Nitrogen, as has been shown by many investigations, is taken up at least to some degree by most plants, chiefly in the form of nitrates and built into plant tissue. It is necessary,

[1]Contribution from the Department of Agronomy, Oklahoma Agricultural and Mechanical College, Stillwater, Okla. Received for publication, December 23, 1923.

[2]Associate Agronomist, Oklahoma Agricultural Experiment Station.

therefore, that the soil conditions be such that the proper amount of this important plant food may become available for crop use.

LITERATURE REVIEWED

Stevens and Withers (8)[3] observed that the nitrifying power of North Carolina soils was low but could be increased by cropping to legumes and by using stable manure.

Whiting and Schoonover (9) reported at the end of four years work that "The most important factor in increasing nitrate production is soil treatment. Climatic factors control the cause of nitrate production, but the amount of production is dependent upon soil treatment. They found that active organic matter greatly increased the amount of nitrates in the soil used (brown silt loam.) A rotation including a legume, green manure also showed a marked superiority in nitrate production.

Allen and Bonazzi (2) show that with continuous wheat culture on Wooster Silt Loam (Ohio), in the nineteenth year nitrate production is much higher on the manured plot than on the untreated plot.

Murphy (5) shows that with a continuous wheat culture on Kirkland loam to silt loam, in the thirtieth year of the experiment nitrate production was much greater on the manured land.

Neller (6) conducted some studies on Sassafras loam soil which showed that nitrate accumulations were higher on limed plots than those not limed.

Albrecht (1) in studying nitrification on plots under continuous cropping to corn and timothy with manure and without manure, obtained results which indicated that nitrate production in manured and unmanured soils is increased by the addition of limestone in both cases.

Harrison (4) reports that the application of either calcic or dolomitic limestone favors nitrification and humus formation and leads to better yields both of green manure crops and the subsequent crop of ragi.

Noyes and Conner (7) report investigations conducted at the Indiana experiment station of five typical acid soils which showed that calcium carbonate additions markedly increased nitrification in all five soils.

Greaves and Carter (3) report, as one of their conclusions of some experiments conducted at the Utah Station regarding the influence of barnyard manure, that the application of manure to a cropped soil greatly increases its nitrifying power.

[3]Reference by number is to "Literature Cited," p. 136.

EXPERIMENTAL WORK

Soils Studied

The principal upland soils of the Red Prairies division of the Great Plains region belong to the Kirkland and Vernon soil series. The predominating material forming these soils is of a sandstone and shale nature. The Vernon soils are formed from red sandstone while the Kirkland soils are formed from a combination of red sandstone and shale. These soils are both residual, the Kirkland being the older soil.

The Vernon soil is characteristically chocolate red in the surface and chocolate red in the subsoil, altho the upper subsoil often is of a brownish color. This soil has a stiff clay to sandy clay subsoil. The drainage is well established, as the soil occupies the rolling to steep lands of the division. It is commonly called the "red upland" by the farmers of the area.

The Kirkland soil is chocolate brown in the surface and of a lighter brown color in the subsoil. Oftentimes the subsoil is more or less yellowish mottled. The surface drainage is fair, but the under drainage is relatively poor, because of the tough impervious compact nature of the subsoil. These soils occupy the more nearly level sections of the area. They are commonly called the brown soils or the soil with a hardpan subsoil. The roots of plants are often restricted by the hardpan subsoil, which not only limits proper moisture conditions but also the feeding area of the roots of crops grown on the land. Crop yields are higher on the Vernon than on the Kirkland soils.

ARRANGEMENT OF PLATS

Vernon very fine sandy loam was the type used to represent the Vernon soils, while Kirkland loam was used for the Kirkland soils. Both soils used were typical of their respective series, the Vernon approaching the shallow phase and having a falling topography typical of the series, while the Kirkland was characteristically almost level and having but fair drainage.

Table 1.—*Fertilizer plan for both soils*

Plot number	Treatment
1.	Check
2.	5 tons ground limestone
3.	2.8 tons calcium oxide
4.	5 tons ground limestone and 8 tons manure
5.	2.8 tons calcium oxide and 8 tons manure
6.	check
7.	3 tons ground limestone
8.	1.68 tons calcium oxide
9.	3 tons ground limestone and 8 tons manure
10.	1.68 tons calcium oxide and 8 tons manure

Ten plots of 1/20 acre each (124.45 ft. x 17.5 ft.) were used for each soil. The same fertilizer plan was followed. The materials as given in the preceding table were applied in the spring of 1917 and the spring of 1921.

A border 7 feet wide separates the Kirkland soil plots from each other while it is 3½ feet wide for the Vernon soil.

Method of Procedure

Except where otherwise noted samples of soil were collected from all of the plots of the two soils once during each of the three growing months, namely, June, July, and August, each year for the last three years (1921–23 inclusive.) The samples were taken from an area 10″ x 20″ x 6″ deep for each plot at each sampling time, but not at the same place any two times during the season. This distributed the samples over each plot for each year. The soil was dug up by means of a sterilized spatula, was well mixed and then a representative sample was placed in a sterilized soil can and taken to the laboratory, where a representative sub-sample was taken from each can and its moisture content determined. The remaining sample of each soil was used in making nitrification and other tests.

For the nitrification test duplicate samples of 100 grams (dry basis) of each soil were placed in sterile glass tumblers and to each, 100 mg. of ammonium sulphate was added. The soil in each tumbler was then well mixed and raised to optimum moisture content for the respective series. The samples were then incubated for four weeks at room temperature. At the end of this time the nitrates present were leached out by adding about 2 gm. of calcium oxide and 200 cc. of distilled water, shaking for 20 minutes and filtering. Nitrates were determined by the phenoldisulfonic acid method.

Results

The following table shows the number of millograms of nitrate in 100 cc. of percolate:

It is evident from the data shown in Table 2, that the various lime

Table 3.—*Showing effect of rate of applying lime on nitrification, (3 year average).*

Soil and treatment	Milligrams nitrate found June	July	August
Kirkland—5 tons of limestone or its equivalent in calcium oxide	7.761	25.116	14.805
Kirkland—3 tons limestone or its equivalent in calcium oxide	6.190	12.091	11.096
Kirkland—check (ave. 2 plots)	2.714	7.186	6.024
Vernon—5 tons of limestone or its equivalent in calcium oxide	12.456	21.550	15.531
Vernon—5 tons of limestone or its equivalent of calcium oxide	8.849	16.050	15.258
Vernon—check (ave. 2 plots)	4.854	5.408	4.771

TABLE NO. 2.—*Showing number of milligrams of nitrate per hundred cubic centimeters of filtrate from each soil.*

	Kirkland loam					Vernon very fine sandy loam				
Month	Plot	1921	1922	1923	Average	Plot	1921	1922	1923	Average
June	1	1.180	2.40	4.000	2.527	1	2.133	5.400		3.766
	2	5.330	8.01	9.000	7.480	2	11.850	17.305		14.577
	3	5.820	9.01	9.600	8.143	3	6.530	14.140		10.335
	4	7.110	9.01	5.733	7.284	4	8.420	14.100		11.260
	5	3.660	9.01	9.800	7.490	5	7.272	17.090		12.181
	6	2.840	3.60	2.266	2.902	6	2.000	9.885		5.942
	7	3.120	3.00	4.800	3.640	7	3.368	10.190		6.779
	8	9.850	3.60	12.800	8.750	8	3.678	18.160		10.919
	9	4.410	6.01	11.200	7.207	9	4.210	13.980		9.095
	10	4.410	6.01	16.400	8.940	10	2.734	12.815		7.774
July	1		8.100	6.560	7.330	1		6.500	5.333	5.916
	2		19.000	38.000	28.500	2		21.600	17.200	19.400
	3		20.800	22.666	21.733	3		28.000	19.400	23.700
	4		10.500	20.666	15.583	4		31.200	19.932	25.566
	5		15.400	18.000	16.700	5		29.200	19.133	24.166
	6		8.933	5.151	7.042	6		5.300	4.500	4.900
	7		12.133	11.000	11.566	7		12.600	16.400	14.500
	8		11.733	13.500	12.616	8		15.400	19.800	17.600
	9		11.266	18.133	14.699	9		20.000	15.466	17.733
	10		17.000	27.333	22.166	10		16.400	12.600	14.500
August	1	1.385	9.057	6.133	5.525	1	2.165	5.666	7.200	5.010
	2	3.415	8.960	20.266	10.880	2	7.770	15.133	22.666	15.190
	3	2.860	30.800	22.533	18.731	3	12.420	15.466	19.733	15.873
	4	3.280	18.132	17.333	12.915	4	9.440	13.400	26.666	16.502
	5	3.730	23.966	16.800	14.832	5	6.480	13.400	22.000	13.960
	6	1.170	9.720	8.680	6.523	6	1.500	3.500	8.600	4.533
	7	2.220	10.120	18.400	10.247	7	8.000	11.800	21.799	13.866
	8	2.640	12.400	20.799	11.946	8	6.590	14.933	28.430	16.651
	9	2.280	14.400	12.933	9.871	9	4.850	15.600	24.400	14.950
	10	3.105	28.666	8.880	13.550	10	5.150	11.600	24.733	13.828

treatments have greatly increased nitrification in both types of soil. As an average, the treated plots have from two to four times more nitrates present at the end of the incubation period. It can also be observed that the highest nitrate production takes place during the month of July.

The heavier rate of application of lime gave the greatest nitrification as is shown by Table 3.

The soils treated with calcium oxide were found to increase nitrification greater than those treated with ground limestone as can be seen from the data in Table 4. This applies to both soil types studied.

TABLE 4.—*Effect of different forms of lime on nitrification (3 year average)*

Soil	Treatment	Milligrams Nitrate Found June	July	August
Kirkland	Ave. all limestone treatments..........	5.560	20.033	10.563
Kirkland	Ave. all calcium oxide treatments......	8.446	17.174	15.338
Kirkland	Ave. all check treatments.............	2.714	7.186	6.024
Vernon	Ave. all limestone treatments..........	10.678	16.950	14.528
Vernon	Ave. all calcium oxide treatments......	10.627	20.650	16.262
Vernon	Ave. all check treatments.............	4.854	5.408	4.771

The influence of manure has not been nearly as great as that of lime in increasing nitrification. Table 5 shows this very clearly. In most all cases where 5 tons of ground limestone or its equivalent in CaO has been used, manure, when added to the combination, failed to cause any further increase in nitrification. With the lighter application of lime (three tons of ground limestone or its equivalent in CaO) the addition of manure in each instance for the Kirkland soil increased nitrification, but for the Vernon soil no appreciable difference occurred.

TABLE 5.—*Effect of manure in combination with lime on nitrification. (3 years average)*

Soil	Treatment	Milligrams Nitrate Found June	July	August
Kirkland	5 tons ground limestone or equivalent in CaO...........................	7.761	25.116	14.805
"	5 tons ground limestone or equivalent in CaO and 8 tons manure............	7.387	16.141	13.873
"	3 tons of ground limestone or equivalent in CaO..........................	6.190	12.091	11.096
"	3 tons ground limestone or equivalent in CaO and 8 tons manure............	8.073	18.432	11.710
"	Check..............................	2.714	7.186	6.024
Vernon	5 tons ground limestone or equivalent in CaO...........................	12.456	21.550	15.531
"	5 tons ground limestone or equivalent in CaO and 8 tons manure............	11.720	24.866	15.231
"	3 tons ground limestone or equivalent in CaO...........................	8.849	16.050	15.258
"	3 tons ground limestone or equivalent and 8 tons manure................	8.434	16.116	14.389
"	Check..............................	4.854	5.408	4.771

SUMMARY

Lime either in the form of ground limestone or calcium oxide increased nitrification in both of the soils studied.

For the three months studied namely, June, July, and August, nitrification was highest during July, for both types of soil.

Of the two rates of application, the heavier rates gave the greatest nitrification for both soils.

The calcium oxide was somewhat more effective in increasing nitrification than was the ground limestone.

Manure did not further increase nitrification, when applied with the heavier applications of lime.

Manure did increase nitrification, when applied with the lighter rate of lime on the Kirkland soil, but not on the more open Vernon soil.

LITERATURE CITED

1. ALBRECHT, W. A. Effect of different soil treatments long continued upon bacterial activity in the soil. Mo. Agr. Expt. Sta. Bul. 189. 1921.
2. ALLEN, E. R. and BONAZZI, A., On nitrification, Ohio Agr. Expt. Sta. Tech. Bul. 7, 1915.
3. GREAVES, J. E. and CARTER, E. S. Influence of barnyard manure and water upon the bacterial activities of the soil. Jour. Agr. Res., 6:889–926. 1916.
4. HARRISON, W. H. Ann. Rpt. Bd. Sci. Advice India, 1917–18, pp. 6, 7. Abs. *in* E. S. R. 42:218.
5. MURPHY, H. F. Unpublished data, Okla. Agr. Expt. Sta., 1923.
6. NELLER, J. R. The oxidizing power of soils from limed and unlimed plots andr elation to other factors. Soil Sci. 10:29–39. 1920.
7. NOYES, H. A. and CONNER, S. D. Nitrates, nitrification, and bacterial contents of five typical acid soils as affected by lime fertilizer, crops, and moisture. Jour. Agr. Res., 16:27–42. 1919.
8. STEVENS and WITHERS. Studies in soil bacteriology. V. The nitrifying and ammonifying power of North Carolina Soils. Centr. f. Bakt.2 abt. 34:187–203. 1912.
9. WHITING, A. R. and SCHOONOVER, W. R. Nitrate production in field soils in Illinois. Ill. Agr. Expt. Sta. Bul., 225. 1920.

THE EFFECT OF CERTAIN FERTILIZERS ON NITRIFICATION[1]

P. E. Brown and R. N. Gowda[2]

It is quite generally accepted now that the increases brought about by the application of fertilizers to soils may not be due entirely to the addition of plant food constituents, but may be in part at least, the result of more intense bacterial action and a consequently greater production of available plant food from the supply already present in the soil. It is even conceivable that in some cases the bacterial effects of fertilizers may be more significant than the chemical. In general, however, fertilizers undoubtedly act mainly in supplying available plant food, while the bacterial changes brought about in the soil are a secondary benefit. The physical conditions in the soil are also often profoundly affected by certain fertilizers and as a result bacterial action in the soil may be much modified.

Evidently a thoro knowledge of the effect of fertilizers on bacteria in the soil is essential to a full understanding of the theory of fertilization and may be of large significance in the final solution of the many problems involved in the practical use of various natural and commercial fertilizing materials.

Among the many bacterial processes occurring in soils, nitrification is of particular interest and importance, inasmuch as this process controls the supply of nitrogen available to plants. While other elements may often be controlling factors in crop production, vigorous nitrification must always occur in soils if yields are to be satisfactory. Furthermore there are indications from some experiments which have been conducted recently that the nitrification occurring in soil, or its nitrifying power, may bear a close relation to its crop-producing power. A study of the effects of certain fertilizers on nitrification may therefore yield results of special value from the practical standpoint.

The influence of applications of farm manure on nitrification has been studied by various investigators. Velbel (21)[3] found large nitrate formation in soils receiving manure. Frankfurt and Duschechkin (5) observed increased nitrification only in the fields on which the manure increased the yield. Heinze (9), Temple (20), Steven (19), Greaves and Carter (8), and White (22) noted nitrification in

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[3]Reference by number is to "Literature Cited," p. 145.

manured soils. Brown (2) found increases in nitrification with applications of manure up to 16 tons per acre, but larger amounts depressed the process. Decreases in the amount of nitrates present in soil brought about by large additions of manure, as noted by some investigators, are believed by Greaves and Carter (8) to be due to the synthesis of the nitrates to proteins, and not necessarily to a depression in nitrification.

The effects of various green manure crops on nitrification have been investigated, with widely varying results. Hill (10) found that the rate of nitrate formation was greatly improved by the presence of green manures, the legumes having the largest effect. Von May (15) noted a depression in nitrification when rye straw, clover hay and cottonseed meal were plowed under singly or in combination. Brown and Allison (3) found a greater effect of cowpea hay and clover hay than of manures on nitrification. White (22) secured strong nitrification in the presence of green manures, but the process was slower with air-dry materials. Several investigators have shown depressions in nitrification from the application of straw, but these experiments need not be mentioned here as straw was not used in the work reported in this paper.

A few experiments have included studies of the effect of fertilizers on nitrification and the results are variable. Hutchinson and Milligan (11) and Jensen (12) found a decrease in nitrification in soils receiving phosphates. Other investigators (24, 17, 14, 1, 6, 23, 16), however, have secured increases in nitrification when phosphates were applied to the soil. Sodium nitrate has been found in some tests to stimulate nitrification (13, 4, 18, 7), but large amounts may have little or no effect, and may even bring about a depression in the process.

The purpose of the work reported in the following pages was to determine the effects of various fertilizing materials such as farm manure, rock phosphate, acid phosphate, sodium nitrate, and certain complete fertilizers on the nitrate content and the nitrifying power of an important Iowa soil type.

EXPERIMENTAL WORK

The soil used in this work was a typical Carrington loam, an extensive drift soil type in Iowa. It had a total nitrogen content of 4900 pounds and a lime requirement (Truog method) of 2 tons per acre of two million pounds. A sufficient amount of $CaCO_3$ to neutralize the acidity and supply two tons additional was added to the soil before any of the treatments were made. Twenty pounds of soil were then placed in glazed earthenware pots in the greenhouse

and the special treatments shown below were made to duplicate pots, being thoroly mixed with the entire amount of soil. The moisture content was then adjusted to the optimum and kept at that point thruout the experiment.

Pots	Treatment
1–2	Check
3–4	8 tons manure per acre
5–6	16 tons manure per acre
7–8	24 tons manure per acre
9–10	36 tons manure per acre
11–12	1 ton rock phosphate per acre
13–14	2 tons rock phosphate per acre
15–16	200 lbs. acid phosphate per acre
17–18	400 lbs. acid phosphate per acre
19–20	100 lbs. sodium nitrate per acre
21–22	400 lbs. sodium nitrate per acre
23–24	2 tons clover hay per acre
25–26	4 tons clover hay per acre
27–28	300 lbs. complete commercial fertilizer per acre
29–30	600 lbs. complete commercial fertilizer per acre

The manure was well rotted, air dried, ground and thoroly mixed. It was analyzed and found to contain 0.421 percent nitrogen in the form of nitrates. The clover hay was dried, ground, and well mixed before being used. The sodium nitrate had a content of 15.87 percent nitrate nitrogen. The 2–8–2 complete commercial fertilizer contained practically no nitrate nitrogen. The amount of nitrate nitrogen added to the soil, per 100 grams, was 0.3886 mgm. for the 8 tons of manure and 0.788 mgm. for the 100 pounds of sodium nitrate. All the applications were made on the basis of pounds or tons per acre of two million pounds of surface soil.

Samples were drawn every two weeks for the determinations of nitrates and the nitrifying power of the soils. In all, five samplings were made. In sampling, the surface soil was removed with a sterile spatula and the sample drawn from the well mixed soil below. The nitrate determinations were made by the phenoldisulfonic acid method. The nitrifying power of the soils was determined by the beaker method, using 100 mg. of ammonium sulfate per 100 gm. of soil in duplicate, adjusting the water content to the optimum and incubating at room temperature for four weeks.

TABLE 1.—*Nitrates in manured soils—at the various samplings*
Expressed in mg. of nitrate nitrogen per 100 gm. of soil.
(Average of duplicate tests on samples from duplicate pots)

Treatment	I 2 wks.	II 4 wks.	III 6 wks.	IV 8 wks.	V 10 wks.	General Average
Check	4.149	1.8648	2.5047	3.519	3.946	3.1967
8 tons manure	4.246	2.664	5.4072	6.213	7.667	5.0394
16 tons manure	5.903	3.110	6.6027	7.166	7.273	6.0109
24 tons manure	6.329	4.250	6.4404	8.884	10.273	7.2353
36 tons manure	12.462	5.171	8.6472	10.511	11.683	9.6948

The nitrate content of the manured soils at the different samplings is shown in Table 1. From this table, it is readily apparent that the application of manure brought about large increases in the content of nitrates, the larger applications showing the greater effects. Only in two instances was there no increase in nitrates when the amount of manure was increased and in both these cases the differences were small. The average figures for the five samplings show a steady increase in nitrates, the largest amount being present when 36 tons of manure were applied. The increases, however, were not proportional to the amount of manure applied, the 16-ton applications giving less than twice as much nitrate as the 8 tons; the 24 tons, about twice as much as the 8 tons; and the 36 tons, about three times as much as the smallest amount. It is evident that even such a large amount of manure as 36 tons per acre did not depress nitrification in this soil.

It may be noted that at the second sampling all the soils contained less nitrate than at the first or at the later samplings. This may be due to the multiplication of bacteria in the soils and the consequent assimilation of available nitrogen in greater amounts. At the later dates, the numbers of these nitrate-assimilating bacteria may have decreased and hence larger amounts of nitrates were found. It is interesting to note however that the effects of the manure show up very similarly even where smaller amounts of nitrates were present. It might be expected that there would be a greater development of the nitrate-assimilating bacteria in the more heavily manured soils and hence the decrease in nitrates would be more pronounced in them and the differences would not be so great between the variously treated soils. Evidently there were some other factors which came into play and affected the ratio between nitrate production and nitrate assimilation.

TABLE 2.—*Nitrification of ammonium sulphate in samples drawn at intervals of two weeks*

Expressed in mg. of nitrate nitrogen per 100 gm. of soil.
(Average of duplicate tests on samples from duplicate pots)

Treatment	I 2 wks.	II 4 wks.	III 6 wks.	IV 8 wks.	V 10 wks.	General Average
Check	9.559	14.885	11.747	12.346	15.097	12.727
8 tons manure	10.030	19.020	14.932	17.177	16.386	15.509
16 tons manure	14.943	20.084	16.007	18.448	19.475	17.791
24 tons manure	12.300	21.321	20.026	24.649	20.845	19.828
36 tons manure	15.258	24.364	20.949	26.683	21.316	21.714

The nitrifying power of the manured soils is shown in Table 2. An examination of this table shows that the effect of manure on the nitrifying power of the soil was similar to its effect on the content of

nitrates. The addition of 6 tons of manure greatly increased the nitrifying power of the soil and every further addition increased it still more, in practically all cases. The average figures for the five samplings show clearly the steady increase in nitrifying power in the soils. Again, it is seen that the increase was not proportional to the amount of manure added, the 36 tons giving only about three times as large an effect as the 8 tons while the 24 tons and the 16 tons gave about twice and one and one-half times the effect of the 8 tons, respectively. Again it is evident that the heavy application of manure did not depress nitrification in this soil.

TABLE 3.—*Nitrates in soils treated with phosphates—at the various samplings.* Expressed in mg. of nitrate nitrogen per 100 gm. of soil. (Average of duplicate tests on samples from duplicate pots)

Treatment	I 2 wks.	II 4 wks.	III 6 wks.	IV 8 wks.	V 10 wks.	General Average
Check...............	4.149	1.8648	2.5047	3.519	3.946	3.197
1 ton rock phosphate..	4.758	2.413	4.3416	3.640	3.856	3.8017
2 tons rock phosphate.	5.675	1.895	3.6338	3.336	3.782	3.6643
200 lbs. acid phosphate	5.432	2.120	3.9600	3.984	4.241	3.947
400 lbs. acid phosphate	3.672	2.529	5.9936	4.239	4.651	4.098

The effect of the phosphate fertilizers on the nitrate content of the soil is shown in Table 3. The results are not very conclusive, as the differences are too small. At the first sampling the rock phosphate increased the nitrate content, the larger amount giving the greater effect; at the second and third samplings the one ton of the phosphate gave an increase, but the two tons gave a much smaller effect; at the third sampling, the larger amount of phosphate seemed to depress the nitrates slightly and the smaller addition had little increasing effect; and at the last sampling both applications seemed to decrease the nitrate content somewhat. The general average for all the samplings, however, shows an increased for both treatments, the larger amount of the rock phosphate having less effect. The acid phosphate increased the nitrate content of the soil at all the samplings, the larger amount giving a greater effect in all cases after the first, where a slight depression over the check was noted with the 400-pound treatment. The duplicates in this case, however, were not satisfactory. Comparing these results with those given in Table 1, it is seen that a similar depression in nitrates occurred at the second sampling, but this was followed by an alternate increase and decrease instead of a continuous increase as noted in the manured soils.

Table 4 shows the effect of the phosphates on the nitrifying power of the soil. The addition of rock phosphate at the rate of one ton per acre increased the nitrifying power of the soil quite distinctly in all but one case. The two tons showed an increase at three samplings,

The steady increase in the nitrate content of the soil treated with clover hay and the almost similar increase in its nitrifying power indicate that given more time for decomposition the treatment might show considerable beneficial effect on the nitrifying power of the soil. It is interesting to note that even in the period of this work the increase in the nitrifying power of the soil with the 4-tons of clover hay was about equal to that in the soil receiving 8 tons of manure.

TABLE 9.—*Nitrates in soils treated with a complete commercial fertilizer.* Expressed in mg. of nitrate nitrogen per 100 gm. of soil. (Average of duplicate tests on samples from duplicate pots.)

Treatment	I 2 wks.	II 4 wks.	III 6 wks.	IV 8 wks.	V 10 wks.	General Average
Check...............	4.149	1.8648	2.5047	3.519	3.946	3.197
300 lbs. complete fertilizer	5.328	2.449	3.5549	3.175	4.320	3.7654
600 lbs. complete fertilizer	6.730	2.631	3.4803	4.051	4.176	4.214

TABLE 10.—*Nitrification of ammonium sulfate by soils treated with a complete commercial fertilizer* Expressed in mg. of nitrate nitrogen per 100 gm. of soil. (Average of duplicate determinations on samples from duplicate pots)

Treatment	I 2 wks.	II 4 wks.	III 6 wks.	IV 8 wks.	V 10 wks.	General Average
Check...............	9.559	14.885	11.747	12.346	15.097	12.727
300 lbs. complete fertilizer	11.692	14.071	15.211	13.045	13.472	13.498
600 lbs. complete fertilizer	10.708	12.022	14.851	12.549	12.625	12.551

The effects of the complete commercial fertilizer on the nitrate content of the soil and on its nitrifying power are shown in Tables 9 and 10. In all but one instance there was an increase in the nitrate content from the treatment and in most cases the larger amount gave the larger effect. The average results show that the 600 pounds gave almost twice the effect of the 300 pounds. Again, as noted with other materials, there was an alternate rise and drop in nitrate content at the different samplings, a decrease at the second sampling being followed by an increase. With the larger amount no further decrease occurred, but with the smaller amount a decrease at the third sampling was followed again by an increase at the last date. It seems evident that this complete fertilizer increased the nitrate content of this soil.

The nitrifying power of the soil was not largely affected by the fertilizer, the 300 pound treatment showing a small increase in the average figures while the 600 pounds showed a decrease. At three of the samplings the smaller amount increased the nitrates but the larger amount gave increases only at two samplings. In all cases, the smaller amount gave greater effects than the larger amount. The results are so irregular that it is difficult to draw definite con-

clusions, but from the average figures it seems that small amounts of the complete fertilizer may bring about slight increases in the nitrifying power of this soil.

SUMMARY

The conclusions which may be drawn from these experiments on the effects of manure, clover hay, phosphatic and nitrogenous fertilizers on nitrification in the Carrington loam soil in the greenhouse are as follows:

Nitrification was increased by applications of manure up to the [illegible]um treatment of 36 tons per acre, as shown by the nitrate [illegible] the soil. The increases from the larger applications were [illegible]proportional to the amount of the application.

The nitrifying power of the soil was increased by the manure up to the 36 ton amount, but the increases were not proportional to the amounts used.

There was no indication of denitrification in the soil receiving the largest amount of manure (36 tons).

Rock phosphates increased the nitrate content and the nitrifying power of the soil.

Acid phosphate stimulated the nitrifying power of the soil and gave a greater nitrate content.

Sodium nitrate increased the nitrate content of the soil and enhanced its nitrifying power.

Clover hay gave a little effect on the nitrate content of the soil, but increased its nitrifying power.

Small applications of a 2–8–2 complete fertilizer gave an increase in the nitrate content of the soil and stimulated the nitrifying power to a small extent.

Periods of intensive nitrification seem to alternate with periods of lesser action, the length of these periods and the time of their occurrence varying with the treatment of the soil.

LITERATURE CITED

1. Ames, J. W. and Richmond, T. E. Effect of sulfofication and nitrification on rock phosphate. *In* Soil Sci., 6:351. 1918.
2. Brown, P. E. Bacteriological studies of field soils, III. The effects of barnyard manure. Iowa Agr. Expt. Sta. Res. Bul. 13. 1913.
3. Brown, P. E., and Allison, F. E. The influence of some common humus-forming materials of narrow and wide nitrogen-carbon ratio on bacterial activities. *In* Soil Sci., 1:49. 1916.
4. Coleman, D. A. The influence of sodium nitrate upon nitrogen transformations in soils with special reference to its availability. *In* Soil Sci., 4:345. 1917.

5. FRANKFURT, S. and DUSCHECHKIN, A. Course of nitrification under the conditions of field experiments. *In* Russ. Jour. Expt. Landw., 8:707-708. 1907. Abst. in Exp. Sta. Rec., 20:519.
6. FRAPS, G. S. Nitrification in Texas soils. *In* Texas Agr. Expt. Sta. Bul. 259. 1920.
7. GREAVES, J. E., CARTER, E. G., and GOLDTHORPE, H. C. Influence of salts on the nitric-nitrogen accumulation in the soil. *In* Jour. Agr. Res., 16:107. 1919.
8. GREAVES, J. E. and CARTER, E. G. Influence of barnyard manure and water upon the bacterial activities of the soil. *In* Jour. Agr. Res., 6.889 1916.
9. HEINZE, B. Humus-bildung und Humus zersetzung in Ackerboden. *In* Centbl. Bakt. Abt. 2, 26:682–683. 1910.
10. HILL, H. H. The effect of green manuring on soil nitrates und[illegible] 3.19 [illegible]use 2 7C conditions. *In* Va. Agr. Expt. Sta. Tech. Bul. 5. 1914.
11. HUTCHINSON, C. M. and MILLIGAN, S. Green manuring experiment. *In* Agr. Res. Inst. Pusa Bul. 40. 1914. Abst. in Exp. Sta. Rec., 31:722.
12. JENSEN, C. A. Nitrification and total nitrogen as affected by crops, fertilizers and copper sulfate. *In* Jour. Amer. Soc. Agron., 8:10–22. 1916.
13. LIPMAN, J. G. and BROWN, P. E. Ammonia and nitrate formation in soils. *In* N. J. Agr. Expt. Sta. Rept., p. 117. 1909.
14. NOYES, H. A. and CONNER, S. D. Nitrates, nitrification and bacterial counts in 5 typical soils as affected by lime, fertilizer, crops and moisture. *In* Jour. Agr. Res., 16:27. 1919.
15. MAY, F. VON. 1914. On the influence of straw on the availability of organically combined nitrogenous fertilizers. *In* Mitt. Landw. Lehrkanz. K. K. Hochsch, Bodenkul. Wien, 2:433–454. 1914. Abst. in Expt. Sta. Rec., 31:822.
16. PATTERSON, J. W. and SCOTT, P. R. Influence of certain soil constituents on nitrification. *In* Jour. Dept. Agr. Victoria, 10:393. 1912.
17. REED, H. S. and WILLIAMS, B. Nitrogen and nitrification in various soil types. *In* Va. Agr. Exp. Sta. Tech. Bul. 3. 1915.
18. SINGH, T. M. Toxicity of "alkali" salts. *In* Soil Sci., 6:463. 1918.
19. STEVENS, F. L. Nitrate in soils. *In* Centbl. Bakt. Abt. 2, 34.64. 1918.
20. TEMPLE, J. C. Influence of stable manure upon the bacterial flora of the soil. *In* Centbl. Bakt., 36:206. 1912.
21. VELBEL, B. The course of nitrification in fallow soil. *In* Khutorianin, No. 10, p. 12–18, 20, 22, 23, 24, pp. 26–28. 1912. Abst. in Exp. Sta. Rec., 31:722.
22. WHITE, J. W. Soil acidity as influenced by green manures. *In* Jour. Agr. Res., 13:171. 1918.
23. WHITING, A. L. and SCHOONOVER, W. R. Nitrate production in field soils in Illinois. *In* Ill. Agr. Expt. Sta. Bul. 225. 1920.
24. WITHERS, W. A. The formation of nitrates in soils. *In* N. C. Agr. Exp. Sta. Bul. 190. 1905.

AN AGRICULTURAL RETROSPECT

(A Book Review)

F. D. Farrell

"Whenever you think you have a new idea, look up the Greeks and see which one expressed it best." This statement by an author whose name I do not now recall suggests one of the best of reasons for reading history. To read history helps to give us perspective and a proper feeling of humility.

We people whose lives and energies are devoted to the welfare of agriculture and country life would do our work better and serve our country more effectively if we knew more than most of us do about the important achievements and interesting lives of our predecessors. It is true that most of us have something of a habit of "reviewing the literature" before we publish the results of our inquiries, and this is as it should be. But comparatively few in our professional fraternity have made this habit include much of the literature of the beginnings of agriculture, even in America. One result of this is that many, perhaps most of us frequently have need to "look up the Greeks."

These are some of the thoughts suggested by a reading of "The Beginnings of Agriculture in America," a book written by Mr. Lyman Carrier of the Bureau of Plant Industry, and published in 1923 by the McGraw-Hill Book Co. The book is an agricultural retrospect which should be of interest and value to any American agricultural student who gives himself the pleasure of reading it. The author is an agronomist and the book is devoted chiefly, but by no means entirely, to subjects of agronomic interest.

Naturally, every member of the American Society of Agronomy is familiar with some of the material which the book contains, but much of the material is new to most of us. Any one of us might give himself a test on the following questions based on a few of the numerous subjects discussed in the book: When and where was alfalfa first grown in North America? What animals did the Indians domesticate? When was barbary eradication first suggested in America? What was Bristol Beer? How did the Indians clear land? When and where did Americans first try to grow cotton as a perennial and with what results? What is the origin of crab grass? When and where was the first American agricultural experiment station established? What American colonies tried communistic farming? What fertilizers, if any, did the Indians use? In what American colonies was irrigation practiced? To what extent did the Indians

practice agricultural cooperation? Was agricultural price-fixing ever tried by the American colonies? Did the colonies have any laws against the use of tobacco? Did Washington and Jefferson grow alfalfa? What colony was famous for its pacing horses? Did any of the colonies suffer from over-production of wheat?

Without subscribing to the general principle of questionnaires, one might suggest that even this one is of some importance and that it might prove embarrassing to several members of the Society if it were sprung on them by some agricultural Thomas A. Edison.

Carrier makes us feel our indebtedness to the sagacity of the American Indian. It gives us a wholesome feeling of humility to read one of the author's enthusiastic statements about the Indian's accomplishments in the improvement of maize. "The Indians," he says on page 43, "had achieved marvelous progress in its culture. It was the most widely grown of all their domesticated plants. . . . . Through the years, perhaps millenniums (in) which the Indians had cultivated corn they so modified its habits of growth that they had strains suitable not only for greatly varied climatic and soil conditions, but for many special purposes of use as well. All the changes and improvements in corn which the white man has been able to accomplish in the past four centuries are insignificant when compared with the work of the Indians with this plant."

The origins and early culture of many of our important plants are treated at considerable length: the potato, cotton, tobacco, corn, peanuts, and many others. Several pages of interesting discussion are devoted to the origin of what has become an American institution —the watermelon. The evidence is interestingly conflicting. The author, an outspoken champion of the Indian, gives the latter the benefit of the doubt, concluding the discussion (page 78) as follows—

> "Until more convincing evidence to the contrary is brought to light, it seems advisable to consider the genus *Citrullus* as common to both hemispheres the same as the common gourd and seven other genera of cucurbits. At present the evidence favors the American Indian as the discoverer and domesticator of the edible watermelon."

Those of us who are directly concerned with the conservation of pastures (and more of us should be than are!) can find in the book a few interesting fragments on that subject. We can learn, for example, that our concern with the question of burning is no new matter among American farmers. A North Carolinian, writing in 1731, is quoted (page 197) as follows—

> "As for Hay, I never observed any made in the
> Country, tho' they have such plenty of Grass,

that they are obliged to burn it off the Ground
every 10th of March, by vertue of a Law made in
the Country for that purpose."

The author must have spent many laborious but happy hours with fascinating old books in the libraries of Washington. The bibliography contains 135 titles, many of them of the sixteenth century. The fact that he quotes copiously from these old treasures is one of the strong points of his book. Several delightful wood cuts, chiefly sixteenth century, are reproduced.

In his modest preface the author practically forestalls adverse criticism when he says that "An adequate history of agriculture in the United States has yet to be written and, when it is, it must, to be reliable, be based on a thorough understanding of farming achievements of the colonists. . . . . It is hoped that this book may assist in future research in the subject." He may be assured that at least one of his readers is convinced that the hope will be realized.

AGRONOMIC AFFAIRS

NEWS AND NOTES

O. C. Bryan has been appointed Assistant Professor of Agronomy at the Florida College and Station.

At the University of Tennessee, former Vice-Dean C. A. Willson has been made Dean of the College of Agriculture, and former Vice-Director C. A. Mooers has been made Director of the Agricultural Experiment Station.

Earl B. Working had been appointed Associate Professor of Milling Industry at the Kansas State Agricultural College.

John Paul Jones, formerly of the College of Agriculture at Cornell University, has been appointed Research Agronomist at the Massachusetts Agricultural College and Experiment Station, effective October 1, 1923.

C. R. Runk, Assistant Professor of Agronomy at the Delaware College of Agriculture, has been made also Assistant Agronomist of the Experiment Station, and will take up special studies of soil acidity.

Dr. E. W. Allen has relinquished the editorship of the *Experiment Station Record*, and H. L. Knight, who has been Assistant Editor (1906–1918) and Associate Editor (since 1918) now becomes Editor of the *Record*.

W. H. Waggaman has resigned as Scientist in charge of Investigations of Fertilizer Resources of the Bureau of Soils of the U. S. Department

of Agriculture, to accept a position with the Victor Chemical works, of Chicago Heights, Illinois, where he will be engaged in investigations with phosphates and phosphoric acid.

M. A. Willis, a graduate of Clemson College, has been appointed as a graduate assistant in the Department of Agronomy at the University of Delaware.

G. E. Thompson, formerly Head of the Agronomy Division of the College of Agriculture of the University of Arizona, has resigned to enter commercial work. R. S. Hawkins has been apointed to fill the vacancy at Arizona.

I. A. Briggs, who has recently completed some graduate work at Iowa State College, has been appointed Assistant Agronomist at the Arizona Agricultural Experiment Station.

E. N. Bressman, formerly Assistant Professor of Agronomy at the Montana State College and Assistant Agronomist of the Montana Agricultural Experiment Station, has been appointed Assistant Agronomist at the Oregon Agricultural Experiment Station, effective January 1, 1924.

Dr. Elmer Drew Merrill, who was formerly connected with the U. S. Department of Agriculture and since 1902 has been engaged in agricultural and botanical work in the Philippine Islands, has been appointed Dean of the College of Agriculture of the University of California. Dr. Merrill went to Manila in 1902 and served first as botanist for the Bureau of Agriculture and Forestry and later as botanist of the Bureau of Science, of which Bureau he has also been Director since 1919. He was also Professor of Botany at the University of the Philippines from 1912 to 1919.

N. E. Winters, who has been in charge of the cooperative investigations in boll-weevil control at Florence, S. C., has gone to Buenos Aires, where he has been appointed Agronomist in the Cotton Investigations of the Department of Agriculture of the Argentine Republic.

Professor S. C. Salmon, of Kansas Agricultural College, addressed the farmers and station and substation agronomists at University Farm recently on the topics "How Certification of Seed Grain is Aiding Kansas Farmers" and "What Alfalfa has done for Kansas."

At a meeting of Central and Substation agronomists, held January 7, 1924, at University Farm, St. Paul, plans were discussed for further standardization of field trials, and a wider introduction of new varieties of recommended farm crops. Before recommending a new variety for distribution to the farmers it must first have the approval

of this group, such decision being made upon the basis of evidence obtained by comparable field trials.

Professor Andrew Boss, Vice-Director of the Minnesota Experiment Station, addressed the farmers and experiment station workers during Short Course Week recently at Bozeman, Montana, on the topics (1) "Should Dairying be Expanded in Montana" and (2) "Readjustments in Production for 1924." Professor Boss observed that surplus farm products should be discouraged and that more prosperity for the farmers would result if flax, wool, mutton, and sugar were produced in greater abundance. These products are imported in quantities into the United States each year, and Montana farmers might do well to increase production along these lines, as they are located where the conditions for production of at least the first three are very favorable.

NEW PUBLISHER FOR THE JOURNAL

Beginning with the January, 1924, issue the JOURNAL will be printed and distributed from the publishing house of W. F. Humphrey, at Geneva, New York. The new arrangement, whereby the editorial and publishing offices are located in the same city, will facilitate many of the details of mechanical operation and tend to make for more prompt distribution of the JOURNAL each month. The new publisher has a fine modern printing plant and assures the editorial staff that he will be able to maintain a high standard of quality of mechanical work on the JOURNAL.

TENTH ANNUAL CONFERENCE OF NEW ENGLAND AGRONOMISTS

Twenty agronomists, members of the New England Section of the American Society of Agronomy, attended all of the sessions of the annual conference which was held at the Parker House in Boston, Mass., on December 7 and 8, 1923.

The following program was carried out in full:

Evening Session, Friday, December 7, 7:30 P. M.

Report of national meeting, with special emphasis on soil survey symposium. Director W. J. Slate, Jr.

What we are doing in Connecticut. Professor M. F. Morgan.

Interpretation of the soil survey as done in Massachusetts, M. O. Lanphear.

A symplified textural classification of soils. Professor A. B. Beaumont. Discussion led by Director S. B. Haskell.

Morning Session, Saturday, December 8, 9:00 A. M.

The need for soil fertility investigations in New England. Director S. B. Haskell.

What should be its outstanding features? Dean F. W. Taylor.

Is there more duplication than is profitable? Professor F. W. Morse.

Maine's plans for the next ten years. Professor G. E. Simmons.

Present status of the Massachusetts program. Professor J. P. Jones.

The fertilizer resources of the soil as related to different crops. Director B. L. Hartwell.

Luncheon Session Saturday, December 8, 12:00 M.

A decade of accomplishments of the New England Section of the American Society of Agronomy, President W. L. Slate, Jr.

In the opinion of those who were in attendance, this was one of the most successful conferences which has been held by the Section.

THE WINTER MEETING OF THE SOCIETY

A meeting of the Society, in joint session with Section O of the American Association for the Advancement of Science, was held in Cincinnati, Ohio, on Friday, December 28, 1923. In the absence of the officers of the Society and of Section O, the retiring vice-president of Section O, Dr. R. W. Thatcher, presided at all of the sessions. About forty persons were in attendance at the sessions during the day, and thirty-nine attended the joint banquet in the evening.

The two sessions during the day were devoted to a symposium arranged by Dr. C. R. Ball on the topic "Research Fundamental to solving Economic Problems on Crop Plants," which included the following papers:

1a. Taxonomy, Dr. C. R. Ball.
1b. Mycology, Dr. C. L. Shear.
2. Morphology, Dr. R. A. Oakley.
3. Physiology, Dr. Wm. Crocker.
4. Cytology, Dr. R. A. Harper.
5. Genetics, Dr. H. H. Love.
6. Biochemistry, Dr. R. A. Gortner.
7. Edaphics (Soils), Dr. J. G. Lipman.

These papers will be published later in the JOURNAL.

At the joint dinner in the evening, Dr. R. W. Thatcher, retiring vice-president for Section O, read his annual address entitled "A Program for Agricultural Development." The address will be published in an early issue of "Science."

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SYMPOSIUM—THE FORAGE PROBLEM

1. THE LARGER ASPECTS OF OUR FORAGE SUPPLY[1]

C. V. Piper[2]

This address will consist mainly of comments on a series of charts which will be shown. Many of the charts will serve to bring to the attention of agronomists some of the major problems on the matter of forage. These charts are to be published in the 1923 Yearbook of the Department of Agriculture, illustrating an article on "Our Forage Supply."

An agronomist's attitude toward the facts will depend on whether he believes or doubts that the farmers have found the best possible solution of the problem of production, when all the factors are considered. Either attitude is germane to discussion during the symposium.

Whether or not American agriculture as it exists is what it should be, deserves consideration, particularly as forage and livestock make up its largest portion. The dinosaur and the Neanderthal man were doubtless wonderfully well adapted to the conditions of their times. It is worth questioning whether our present agriculture is as well adjusted as it might be to all the factors. That it exists thus and so, does not prove that it may not be more or less comparable to the dinosaur of old.

Some people seem to think that the injunction "Man shall not live by bread alone" means "Eat more meat." Inasmuch as about five-sixths of American agriculture is forage production and animal husbandry, it would seem that this interpretation is uncalled for.

[1]Abstract of address at opening of symposium program, Chicago, Ill., November 12, 1923.

[2]Agrostologist in charge of Forage-crop Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C.

Agronomists are apt to think mainly of problems of production. It is well also to consider what becomes of the produce of the crops. This will aid in a better comprehension of agriculture as a whole.

The following series of charts was displayed and discussed:

1. Acres Used for Production of Forage, of Food, and of Other Crop Products, 1919.
2. Acreage of All Crops and the Approximate Number of Acres Devoted to the Production of Feed for Animals in Each Section of the United States, 1919.
3. Percentage of Total Crop Acreage Harvested Which is Devoted to the Feeding of Farm Animals, 1919.
4. Relative Farm Values of All Crop Products Used for Forage and Those Used for Food, 1919.
5. Human Population and Animal Population, 1919.
6. Animal Surpluses and Deficiencies, 1919.
7. Relation of Human Population to Animal Population in Europe.
8. Comparative Curves of Population All Cattle, Swine, Sheep, Beef Cattle, Dairy Cattle, 1860–1920.
9. All Harvested Forage, 1919.
10. Relative Importance of Major Crop Plants as Forage Producers, 1919.
11. Concentrated Feeds Eaten by Livestock, 1919, and the Number of Cattle Each Item would Support for one year.
12. Hay and Fodder Crops, 1919.
13. Production of Hay in the United States, 1870–1920.
14. Hay Production, 1919.
15. Comparative Yields of the Principal Hay and Fodder Crops, 1919.
16. Straws and Stovers. Total Production, Amount Eaten by Livestock, and Number of Cattle each Item would Support for One Year.
17. Silage, Root Crops, etc. Production, Annual Ration and Number of Cattle each Item will Support for one Year.
18. Crops cut for Silage (mostly Corn); Production, 1919.
19. Relative Prices of Corn and Alfalfa Hay at Kansas City, Mo., 1910–1921.
20. Native Vegetation of the United States.
21. Native Grass Areas of the United States.
22. Pasture Lands by Classes, North, South, and West.
23. Wild, Salt or Prairie Grasses; Acreages, 1919.
24. Leguminous Hay Production, 1919.

25. Sorghums Harvested Both for Forage and Grain; Acreage, 1919.
26. Timothy Acreage, 1919.
27. Clover Acreage, 1919.
28. Alfalfa Acreage, 1919.
29. Miscellaneous Tame Grasses; Acreage, 1919.
30. Small Grains Cut for Hay; Acreage, 1919.
31. Annual Legumes Cut for Hay; Acreage, 1919.
32. Coarse Forage Production, 1919.

The outstanding facts which were emphasized are as follows:

One-fifth of all tilled land in the United States is used to produce non-animal human food (bread, fruits, vegetables, nuts, sugar, oil).

One-tenth of all tilled land in the United States is used to grow cotton, tobacco, etc.

Seven-tenths of all tilled land in the United States is used to produce feed for livestock.

Harvested forage provides only one-half enough feed. Therefore pasturage supplies the other half.

Pasturage costs less than one-fourth as much as would the same amount of feed harvested.

Permanent pasturages of all kinds are about eighty percent of the total pasturages.

2. HAY CROPS

A. FERTILIZING TIMOTHY AND CALCULATING FINANCIAL RETURNS[1]

A. F. Gustafson[2]

Timothy has long held a high place as feed for work horses, particularly in the great cities. The demand from this source is now greatly reduced thru the large displacement of horses by motor-driven vehicles. Whether this displacement has gone too far, as claimed by the horse men, or will go still further, only the future can determine. The present price of gasoline tends to increase the number of motor vehicles, while the low price of hay favors the horse. It does not appear, however, that the city demand for timothy hay will increase during the next few years; indeed it is doubtful if the present demand will be sustained. Farm economists

[1]Paper read as a part of the symposium on "The Forage Problem" at the meeting of the Society held in Chicago, Ill., November 12, 1923.

[2]Extension Professor of Soil Technology, Cornell University, Ithaca, N. Y.

are now urging hay producers to make radical readjustment in their rotations so as to reduce the acreage devoted to growing timothy for several consecutive years. The problem confronting hay producers in New York today is not so much how to fertilize timothy hay for profit as how to grow it and secure a labor income. This statement may seem a bit startling to anyone who has studied recent experiment station bulletins without figuring the returns using present hay prices and present fertilizer and labor costs.

EXPERIMENTS IN FERTILIZING TIMOTHY

Many experiment stations, particularly in the East, have conducted much valuable experimental work in fertilizing the timothy crop.

Schuster (1)[3] reports the results of fertilizing timothy hay for nine consecutive years on the same land. Commercial plant food was used without manure. All plats received 1200 pounds of burned lime to the acre. There was but a single check plat, and no duplication of treated plats. Table 1 summarizes the results obtained.

TABLE 1.—*Nine-year average yield of timothy and increase from treatment.*

Plat	Treatment	Pounds per acre	Average yield of hay to the acre pounds	Increased yield from fertilizer pounds
1	Nitrate of soda	150	3921	467
2	" " "	300	4585	1131
3	Sulphate of ammonia	150	4502	1048
4	Nothing		3454	——
5	Nitrate of soda	150		
	Acid phosphate	125	4730	1276
	Muriate of potash	50		
6	Nitrate of soda	150		
	Acid phosphate	125	4371	917
7	Nitrate of soda	150		
	Muriate of potash	50	4854	1400
8	Acid phosphate	125		
	Muriate of potash	50	4567	1113

The check plat gave a relatively high yield; hence, the apparent increases from fertilizer are less than might have been expected.

Haskell (2) reports the results of thirty years of fertility work in a somewhat irregular rotation, including hay, which was grown two consecutive years on limed and unlimed land without manure. Table 2 gives the yields on limed land, together with the increases resulting from the various fertilizer treatments compared with the average of the check plats.

It would appear that plat 3 was abnormal as phosphorus should not decrease the yield. The increase from nitrogen was small and an abnormally large increase was produced by potassium on plat 5. The most effective combination of two elements was phosphorus and

[3]Reference by number is to "Literature Cited," p 164.

TABLE 2.—*Effect of soil treatment on yield of hay in rotation, North soil test—limed, no manure, average of five crops.*

Plats	Treatment	Pounds per acre	Yield of hay pounds	Increase from treatment pounds
1–4–8–12	None.		1707	——
2	Nitrate of soda.	160	2490	783
3	Dissolved bone black.	320	1407	—300
5	Muriate of potash.	160	3840	1953
6	Nitrate of soda. . . . . Dissolved bone black.	160 320	3617	1910
7	Nitrate of soda. . . . . Muriate of potash.	160 160	3498	1791
9	Dissolved bone black. . . . . Muriate of potash.	320 160	3967	2260
10	Nitrate of soda. . . . . Dissolved bone black. . . . . Muriate of potash.	160 320 160	4872	3165

potash, while a combination of all three into a complete fertilizer gave the largest yield. In another experiment the plat which received 15 tons of manure produced 5060 pounds of hay as compared with 2310 pounds of hay grown with 160 pounds of nitrate of soda.

Lyon and Bizzell (3) report results of fertilizing a six-year rotation, corn, oats, wheat and timothy three years, all of the fertilizer being applied to the timothy, as shown in Table 3.

TABLE 3.—*Yields of timothy hay without manure and increase in yield from fertilizers, average of six crops, 1905–1913. Increase computed from nearest check.*

Plat	Treatment applied on each timothy crop	Pounds per acre	Yield of hay, average of six crops pounds	Increase in yield of hay pounds
711	None.		3185	——
712	Acid phosphate.	320	3688	503
713	Muriate of potash.	80	3806	571
714	None.		3235	——
715	Nitrate of soda.	160	4623	1388
716	Nitrate of soda. . . . . Acid phosphate.	160 320	4620	1905
717	None.		2715	——
718	Acid phosphate. . . . . Muriate of potash.	320 80	3760	1045
719	Nitrate of soda. . . . . Muriate of potash.	160 80	4885	2204
720	None.		2681	——
721	Nitrate of soda. . . . . Acid phosphate. . . . . Muriate of potash.	160 320 80	5335	2654
731	Manure.	20000	5071	3053

Further results with larger amounts of nitrogen and phosphorus are given, but the above are comparable with the figures from the other stations. These data are most consistent.

Gardner, Noll and Lewis (4) report forty years' results with fertilizing a rotation of corn, oats, wheat and hay without manure.

Nitrogen, as dried blood, applied during alternate years at a rate equivalent to 140 pounds of nitrate of soda, gave a lower yield than the average of the check plats. This decrease is charged to acidity resulting from dried blood. Six tons of manure applied on alternate years for corn and wheat gave, as a 40-year average, an increase of 1615 pounds of hay over the nearest check plat. Two hundred pounds of muriate of potash alone, gave a decrease of 121 pounds while 300 pounds of acid phosphate, alone, yielded 710 pounds above the check plats. Combinations of all three without manure gave, as would be expected, larger yields than any constituent alone or any two in combination and about the same as did the six-ton application of manure.

Miller and Hudelson (5) report a thirty-year average yield of 4902 pounds of timothy hay grown continuously with 6 to 7.8 tons of manure to the acre applied annually. The increase over no treatment was 2325 pounds of hay.

Increases from Nitrate of Soda

The average increase in yield of timothy hay from an application of approximately equivalent amounts of nitrate of soda ranges from 467 pounds of hay from 150 pounds nitrate at the Delaware Station to 1388 pounds from 160 pounds nitrate applied on three years of timothy in a six-year rotation on Caldwell Field at Cornell. The Massachusetts experiment station secured an increase of 783 pounds of timothy from the same quantity of nitrate of soda to the acre. The increases at these three stations averaged 879 pounds of timothy to the acre from this quantity of nitrate of soda. Heavier applications gave higher yields but not in proportion to the nitrate applied.

Effects of Manure

The reported increases from farm manure are brought together in Table 4.

TABLE 4.—*Increase in timothy hay from manure.*

Station	Number of crops	Manure to the acre annually on the average	Increase in yield of hay
		tons	pounds
Pennsylvania	40	3*	1615
Missouri	30	6–7.8	2325
Cornell	6	6.7	3053
Ohio	21	1.6*	956

*Residual effect, only, on hay.

From these data, it may be seen that timothy responds well to heavy applications of manure. Even the three-ton per acre application is heavier than can be made with the manure produced from the

crops grown on quite productive soils. Yet, as will be shown later, the increased yield of timothy pays well for manure particularly when its effect on the crops following in the rotation is considered.

The necessary brevity of this paper precludes citing extensive additional data.

SOME FINANCIAL CONSIDERATIONS

From the standpoint of the farmer, it is desirable to know what increase in yield a given fertilizer treatment has made, as shown in the above tables, and what financial returns he may reasonably expect if he follows a similar method of fertilization. The farmer needs definite information as to whether returns will be large enough to justify the expectation of a reasonable net profit under his farm conditions, which are seldom as good as on fertilizer plats.

It is desirable that experiment stations report in their bulletins the actual yields, together with period averages and the fertilizer and crop prices used in calculating the value of the increased crops resulting from the use of fertilizers or other soil treatment. This problem of figuring profits from the use of fertilizers was discussed by Warren (6) in the proceedings of this Society in 1912, and by Thorne (7) and Warren (8), in the JOURNAL of this Society established the following year. At that time Dr. Warren called attention to the fact that several items of expense in connection with the application of fertilizer and with the harvesting and marketing of the increase produced by fertilizers was being ignored. Owing to the omission of such important items of expense the farmer may be misled.

The writer wishes to suggest the following principles which may apply to figuring the value of the increase resulting from fertilization of any crop equally as well as to hay. In doing this the writer would have the suggestions, in so far as they may be constructive criticisms, apply equally to published work with which he has assisted as to publications in general. His only hope is that the real facts may be established.

To the cost of the material, lime or fertilizer, delivered at the farmer's railroad station is to be added: (1) the cost of hauling it to the farm; (2) the cost of spreading, particularly when a special field operation is required as, for example, spreading limestone for subsequent clover, or top-dressing timothy with a single carrier of nitrogen or with a mixed fertilizer; (3) interest on the outlay for treatment including labor. If the material is purchased on credit, interest should be charged only on the outlay other than for materials, but the price paid in such cases is usually much higher than a cash price.

The increased yield should be credited to the treatment at the "field" value of the crop. By the term "field" value is meant the market price less all the expenses of harvesting the increase, storage, insurance, taxes, preparing it for sale and hauling it to market, and any other necessary outlay. The crop increase from fertilizer must carry its own proportionate share of the expense of harvesting and marketing.

With hay this calculation is comparatively simple. There will be some additional expense of cutting and raking the increased yield as compared with these operations on the crop of untreated land, but this item may be passed as insignificant. From the time the hay is raked, however, each ton must bear its own expense for: (1) hauling to the barn, (2) cost of storage or use of buildings, (3) insurance, (4) baling, (5) hauling to market. "Farm value," as used in government reports and sometimes used in fertilizer-increase calculations, is considerably higher than what is here designated as "field" value.

The following is a hypothetical case for the purpose of illustration. An experiment station buys limestone at six dollars per ton at the railroad station, applies it for clover at the rate of one ton to the acre and secures an increase of a ton of hay, mostly clover. No. 2 hay is now (October, 1923) selling, baled and delivered to the buyer, for fifteen to seventeen dollars a ton in up-state New York. (It should be noted however that a very large portion of New York's hay crop is not up to No. 2 grade and consequently has a considerably lower

TABLE 4.—*Methods of figuring "profit" from liming.*

1. Common method:		
Value of hay $16.00 a ton, baled, delivered hay—1 ton increase		$16.00
Cost limestone at station—1 ton		6.00
"Profit" from liming an acre		$10.00
2. Proposed method:		
Cost of limestone at station	$6.00	
Hauling to field and spreading	2.50	
Interest on investment, 2 years[a] at 6 %	1.02	
Total cost of liming an acre		$9.52
Expense on each ton of hay increase:		
Hauling hay to barn from windrow	$1.71	
Use of equipment	.33	
Use of barn, interest, taxes (9), insurance[b], etc	1.29	
Baling	3.63	
Hauling to market	2.00	
Total expense a ton	$8.96	
Net "field" value of a ton of hay, $16.00–$8.96		$7.04
"Profit" (or loss in fact)		—$2.48

[a]Two years usually elapse from time of applying lime until the hay is marketed. Man labor is charged at 38 cents and horse labor at 16½ cents an hour. Farm Management data, 1923.

[b]Average costs 1914–1918. These have not changed materially.

value.) A common method of figuring "profit" from the above experimental data is contrasted below with a proposed method which it is hoped will give a more accurate picture of what the farmer may expect from soil treatment.

One method shows an apparent profit of ten dollars an acre, the other a loss of $2.48. With hay at $20.00 a ton there would be a direct profit of $1.52 an acre.

This calculation does not take into consideration that the treatment improves the quality of the entire crop, nor the indirect benefit of the clover to succeeding grass and cereal crops. When these benefits are considered there would probably be a real but only very moderate profit from the use of limestone under these hypothetical conditions. When farmers use limestone with the real situation fully in mind, they are more likely than otherwise to become regular users of limestone for clover on soils having a considerable lime-requirement.

Nitrate of Soda not always Profitable

Nitrogenous fertilizers have been generally recommended for top-dressing timothy and they do increase the yield. As cited above, long continued work of three experiment stations shows an average increase of 879 pounds of timothy hay to the acre from an application of 160 pounds of nitrate of soda. Consider carefully all the costs of this treatment under present conditions.

The 1923 spring credit price of nitrate of soda was $69.75 a ton delivered to the local dealer.

TABLE 5.—*Value of increased yield from 160 pounds of nitrate of soda to the acre.*

Cost of nitrate of soda to dealer	$69.75	
Dealers margin	5.25	
Hauling to farm	2.00	
Total cost, ton	$77.00	
Cost of 160 pounds of nitrate of soda	$6.16	
Spreading over one acre	.70	
Interest, average, about 4 months at 6%	.13	
Total cost of fertilizing an acre with 160 pounds of nitrate of soda		$6.99
"Field" value of 879 pounds of hay at $7.04 a ton		3.10
Net value of increased yield to the acre		$3.89

This shows a loss of $3.89 an acre so treated. Here again there may be some enhancement in value of entire crop by improving its quality and some benefit to succeeding crops from the larger quantity of organic matter left in the soil by a larger timothy crop. On the other hand, some purchasers object to hay from fertilized land, claiming it to be less palatable.

The writer has no desire to discredit fertilizers. He wishes rather

to raise some pertinent questions with which extension men are confronted almost daily in correspondence, meetings, or conferences.

There are three variables to be considered: (1) cost of materials for soil treatment; (2) cost of labor; and (3) selling price of the crop. It is obvious that any drop in the cost of lime or fertilizers, or any reduction in the total labor charge of applying materials and of harvesting, storing and marketing the increased yield reacts favorably on the net results from soil treatment. A factor which has a much greater effect is the selling price of the crop. Suppose the hay produced were No. 1 in grade, or that the price of No. 2 were $20.00 a ton. This new valuation of the hay would give a direct profit from liming and would reduce the loss of $3.89 from use of 160 pounds of nitrate of soda to the acre on timothy to $2.14 an acre. The farmer is inclined (and properly so, on account of the business hazards assumed) to expect a total profit of twenty to thirty percent as a minimum on such short time investments as fertilizing a hay crop. Hence, in the light of these figures, it does not appear that, with hay at pre-war prices and with nitrate of soda at a much higher level, top-dressing timothy with commercial nitrogen is a paying proposition for the farmer. In this connection, it should be noted that nitrogen is the most expensive ingredient of fertilizers. A smaller increase in yield from acid phosphate, alone, or in combination with muriate of potash, may be profitable because of their low cost as compared with carriers of nitrogen. Carriers of potash are now essentially on the same price level as hay and acid phosphate is much nearer to it than are nitrate of soda and sulfate of ammonia. In fact the twenty-dollar valuation of hay would permit several of the above treatments to show a slight profit. It is to be hoped that prices may soon shift so that more fertilizer can be used to the farmer's economic advantage. It should be more fully appreciated that negative experimental results are equally as valuable as positive ones.

Common but Erroneous Methods

Larger increases were secured at some stations from two ingredients, as nitrate of soda and muriate of potash, or from these with acid phosphate, making a so-called complete fertilizer. A common method of figuring the results from these treatments is to charge against the increased yield the cost of the nitrate of soda, acid phosphate and muriate of potash at the price paid by the institution, without including other necessary expense such as shown above. This will make an apparent good showing for the fertilizer, but is hardly the true situation. Some station workers who figure the

value of increases on this basis discourage home-mixing, and recommend a mixed fertilizer based on the increases secured. But to get a true view from the farmer's standpoint it will be necessary to charge the fertilizer used at the going price for ready-mixed commercial fertilizers rather than at the price of unmixed chemicals, because the ordinary price of ready-mixed goods is always considerably higher than is paid for unmixed fertilizer chemicals.

Manure a Profitable Fertilizer for Timothy

Manure has shown consistently good results in the production of timothy. It furnishes nitrogen, phosphorus, and potassium, in proportions that promote good growth of grasses. On the basis of the results from the three-ton application of manure shown in Table 4, giving an increase of 1615 pounds of hay to the acre, at $7.04 a ton "field" value, the manure was worth $1.90 a ton applied on the one crop. This is the residual effect of manure applied for other crops. At $20.00 a ton for hay this manure was worth almost $3.00 a ton. At present manure is the most economical single fertilizer for timothy hay.

Not long since, when timothy was a good cash crop, it was profitable to apply much, or all, of the fertilizer for the rotation on the hay. It is quite probable that, with the present gloomy outlook for hay, this practice may well be changed and the soil treatment applied on what may be considered the best one or two money crops in the rotation, on the theory that the best money crops in the rotation should have "preferred" treatment. It would seem that where potatoes or cabbage are grown much of the fertilizer, particularly the phosphorus, may well be applied to them; or where wheat or other grains are sown, they may well receive sufficient phosphorus to provide for the succeeding hay crops and more or less manure be applied to the timothy. Under present conditions, it is likely that in many sections this treatment will be most economical for the farmer.

In general, farmers or extension men need to know the actual yields by years or period averages, the prices of fertilizers and crops, labor, and other legitimate charges. These data would enable one to recalculate for his own crops under his conditions. Even so, for the benefit of those who cannot for lack of time, or for other reasons, make their own calculations, the writer urges that crop prices low enough to approximate "field" values and fertilizer prices such as paid by the farmer be used as the basis for advice to be given to him. It is particularly important that these points have full consideration during periods like the present of falling price levels on hay and grains.

ACKNOWLEDGMENT

The writer desires to express to members of the Agronomy and Farm Management Departments of Cornell University, his appreciation of their svmpathetic cooperation in preparation of this manuscript.

LITERATURE CITED

1. SCHUSTER, G. L. Management of meadows and pastures. Del. Agr. Exp. Sta. Bul 130. 1922.
2. HASKELL, S. B. A thirty-year fertility test. Mass. Agr. Exp. Sta. Bul. 212. 1922.
3. LYON, T. L. and BIZZELL, J. A. Experiments concerning the top-dressing of timothy and alfalfa. Cornell Univ. Agr. Exp. Sta. Bul. 339. 1913.
4. GARDNER, F. D., NOLL, C. F., and LEWIS, R. D. Forty years results with fertilizers. General fertilizer experiments. Penn. Agr. Exp. Sta. Bul. 175. 1922.
5. MILLER, M. F., and HUDELSON, R. R. Thirty years of field experiments with crop rotation, manure and fertilizers. Mo. Agr. Exp. Sta. Bul. 182. 1921.
6. WARREN, G. F. Some business questions involved in the interpretation of fertilizer tests. Proc. Amer. Soc. Agron. 4:62–65. 1912.
7. THORNE, C. E. Interpreting fertilizer tests. Jour. Amer. Soc. Agron. 5:129–136. 1913.
8. WARREN, G. F. Further notes on interpreting fertilizer tests. Jour. Amer. Soc. Agron. 5.137–140. 1913.
9. WARREN, G. F., HART, VAN B., MYERS, W. I., GILLETT R. L., NOBLE, C. V., et al. Cost accounts for six years on some successful New York farms. Cornell Univ. Agr. Exp. Sta. Bul. 414. 1923.

2. HAY CROPS

B. PROBLEMS OF ALFALFA IN THE EAST[1]

J. F. COX[2]

The production of alfalfa is undergoing a remarkable shift—decreasing in western alfalfa growing states, and increasing phenominally in the "corn-belt," Great Lakes, New England, and eastern states. More alfalfa is being grown in, or nearer to, the dairy and live stock regions, where consumption is greatest and where production costs must be cheapened.

Prevailingly high freight rates since the war have prohibited extensive hay shipments from western hay growing sections to distant eastern consuming areas. Alfalfa seed has replaced the bulky hay crop, as the leading cash crop in many of these formerly important

[1]Paper read as a part of the symposium on "The Forage Problem" at the meeting of the Society held in Chicago, Ill., November 12, 1923.

[2]Professor of Farm Crops, Michigan Agricultural College, East Lansing, Mich.

western hay shipping districts. The stimulation of the production of native grown seed, particularly in the northwest, during the war period and since, has been followed by greater dependability and success in sowing alfalfa as the native seed came into common use in Wisconsin, Michigan, New York, Indiana, Ohio and other states in the eastern half of the United States.

In answer to a brief questionnaire, agronomists of twenty of these eastern states (Minnesota, Wisconsin, Michigan, New York, New Hampshire, Vermont, Massachusetts, New Jersey, Rhode Island, Pennsylvania, Ohio, Indiana, Illinois, Iowa, Missouri, Kentucky, Maryland, North Carolina, Arkansas and West Virginia) reported a total alfalfa acreage of 1,295,000 acres in 1919 and 1,927,000 acres in 1923—an increase of 632,000 or approximately 50%, during a four year period. These same agronomists, reporting for their individual states, estimate that under present economic conditions the alfalfa acreage could very well be expanded to a total of over 3,000,000 acres, or two and one-half times the present acreage, without danger of serious over-production in eastern states. Alfalfa is possibly the only general crop which twenty careful agronomists would agree upon as being one which should be extensively increased over a wide area, under the conditions which now prevail.

NEW ALFALFA PROBLEMS

With the great eastward shift in alfalfa growing, many new problems are presented for solution.

Seed

The seed supply is without doubt the most important. Only a few stations report extensive and carefully handled plat tests of seed from the many sources now supplying the market. Grimm alfalfa has been shown to be superior in Minnesota, Wisconsin, Michigan, Ontario, northern Indiana, and northern Iowa,—but just where is the southern-most line located, beyond which northwestern grown common alfalfa is equally hardy or more profitable than Grimm?

Tests in "corn-belt" and northern states show that native grown seed of both the Grimm and common varieties, from Utah, Idaho, Montana, the Dakotas, and Kansas, is dependable, and that seed from Arizona, southern California, and Peru is worthless in these districts. What of the seven and one-half million pounds of plump, clean, attractive Argentinian seed imported into the United States in 1923 and offered for general sale, much of it in the above territory? How will it yield in the northern and central states, and what is its real range of adaptation?

Michigan tests, for one year with Argentinian seed and of longer duration with seed from other South American countries, apparently show that this South American seed is not adapted. Chilean seed is also being offered for sale in Michigan (and, without doubt, in other states) at cheaper prices than prevail for native adapted seed. South American seed is another new development on the American market.

The unadaptability, in northern and "corn-belt" states, of Turkestan, Mediterranean and Arabian seed has been fairly well shown; but there is still much to be done by individual state experiment stations in testing out the productivity of the seed supplies on the general market, and furnishing farmers with definite knowledge as to reliable seed and dependable sources of supply. To buy just "alfalfa seed" on the present open market may be compared to buying "a pig in a poke."

Farmers cooperative alfalfa seed growers' organizations in Idaho, Utah, and in North and South Dakota, and cooperative seed distributing organizations in Michigan, New York, Pennsylvania, Ohio, Indiana, Virginia, and the New England states, have made rapid advancement in the securing for sale of alfalfa seed of known and guaranteed source of production and variety. These organizations, and commercial seed companies following similar policies in selling alfalfa seed, have been a great influence in placing alfalfa growing on a safer basis. They are, however, in constant need of careful field tests of seed of various varieties of alfalfa, produced in many localities, to aid them in their efforts properly to guide distribution according to adaptation.

The problem of the desirability of properly staining imported alfalfa seed to designate its source, in order to insure its distribution in localities where it is of known adaptation, and to keep it out of sections where it will result in failure, has been advanced and is being seriously considered. Seed of unknown origin is unsafe seed.

The eastern production of alfalfa seed, while not yet on a large scale, may become an important factor in stabilizing the alfalfa crop in eastern states. Agronomists of Minneosta, Wisconsin, Michigan, Ontario, and Vermont report that alfalfa seed is being produced in their states. Minneosta produced 3,500 bushels, Wisconsin 2,500 and Michigan 6,500 bushels in 1922. The development of adapted strains, which will produce seed advantageously under eastern conditions, may solve this great problem. Such a strain as the Hardigan, which has been developed by Professor F. A. Spragg at the Michigan Agricultural Experiment Station and is now in quite

extensive production, has given satisfactory yields, even under the adverse conditions of 1923, in Michigan. The LeBeau, a variegated variety grown for the past thirty-seven years in Monroe County, Michigan, furnished 5,000 bushels of Michigan's seed in 1922. The 1923 crop was very small because of adverse weather conditions. Only in favorable years can large crops be expected, unless more is learned about seed production. Soil adaptation and fertility requirements, moisture, temperature, and other factors regulating alfalfa seed production under eastern conditions, furnish original and almost virgin fields for scientific investigation. More practical knowledge of when and how often to cut for seed and how best to handle the seed crop is also needed.

Liming

Liming the land is usually necessary to secure success with alfalfa under eastern conditions. Improvements in methods of determining the lime requirement of soils in the field will undoubtedly increase the use of lime for alfalfa and aid in placing alfalfa on soils where it is best adapted. The application of the "Soil Tex"* method has been of much use in the Michigan alfalfa campaigns. It is noticeable that hardier strains, such as the Grimm and Hardigan, often thrive on soils of slightly acid reaction. The exact acidity tolerance, or calcium and magnesium deficiency tolerance, of various strains of alfalfa offers a nice problem.

Varietal Adaptability

Without doubt, certain varieties of alfalfa are better adapted than others for planting on heavy, poorly drained soils. The Grimm, Hardigan and LeBeau have given noticeably better results than common alfalfa under such conditions in Michigan. The problem of special alfalfas for different soil types has received but little attention.

Inoculation

Methods of inoculating soils for alfalfa have been greatly improved and the establishment of bacteriological laboratories (state and privately owned) for the distribution of reliable cultures has been a great aid in insuring crop success. There are, however, many bacteriological problems yet to be solved: such, for example, as the length of time soils will remain inoculated with the proper bacteria for alfalfa; the conditions where inoculation is advisable and where

*A convenient method for determining the approximate lime requirement in the field, developed by C. H. Spurway, of the Soils Department, Michigan Agricultural College, in 1922.

unnecessary; and the effect of soil acidity and other soil conditions on *Pseudomoas radicicola* in causing nodules on alfalfa roots.

Insect Pests and Diseases

A crop as succulent as alfalfa is likely to be affected by a host of insect pests and plant diseases. The alfalfa nematode, hitherto confined to the west, has recently appeared in New Jersey and may possibly appear in other eastern states. Extensive yellowing of fields associated with leafhopper injury, occurred in Michigan in 1922 and 1923, and may become a factor in causing large losses. Without doubt the crop will present many new problems for entomologists and plant pathologists, as the acreage increases.

Cutting for Hay

Recent work at the Kansas and Wisconsin Experiment Stations indicates that the common ideas in regard to the proper time and frequency for cutting alfalfa for hay may not be soundly based, and that possibly many alfalfa growers have been cutting at too early a date and too frequently for the good of the crop. There is still considerable variance in methods of curing and handling the crop, even under similar conditions, and hence opportunity for careful investigation.

Alfalfa for Pasturage

The New England states, and Virginia, West Virginia and Maryland report a great increase in the use of alfalfa in pasture and meadow mixtures. Michigan, Indiana and Wisconsin report a much more extensive use of alfalfa in pasturing dairy stock, hogs and sheep. The value of alfalfa as a pasture crop is becoming better understood. However, little has been done in the way of comparisons of alfalfa with other legumes, and with pasture grasses, for pasture purposes. An extensive field for investigation is presented to those who are interested in determining the place of alfalfa in meadow mixtures and when used for pasture purposes.

The Economics of the Alfalfa Crop

Farm management studies have shown that alfalfa ranks as one of the most profitable of the field crops which are now being grown as a feed crop or as a cash crop. Farms on which alfalfa is grown show much greater profits than those on which alfalfa is not included in the cropping system. There is need for more work on the part of economists and farm management specialists in showing the real value of this crop to the individual farmer and to the community, and its place in the cropping system.

Enough is now known about the handling of alfalfa to insure

dependable results throughout the northern two-thirds of the eastern half of the United States. Farmers who buy adapted seed and plant on a well-prepared, properly firmed seedbed, at the right depth and at the proper season, liming, manuring and fertilizing where necessary, may count alfalfa as one of the most dependable hay crops.

While many experimental problems still present themelves, the big problem of growing alfalfa profitably has been solved and the present task before agronomists is largely an extension problem. It is incumbent upon them properly to encourage this crop in all those regions where it gives better results than other leguminous hay and pasture crops. There is place for some of the old-time fervor of Joe Wing, the great alfalfa evangelist, in modern movements to promote the increase in alfalfa growing. With added experience and a more adequate seed supply, the rapid expansion in alfalfa acreage, even to two and one-half times the present eastern acreage, which agronomists think advisable, is fully warranted.

2. HAY CROPS

C. THE GROWTH OF ALFALFA WITH VARIOUS CUTTING TREATMENTS[1]

L. F. GRABER[2]

The responses of alfalfa to various cutting treatments are far more pronounced than was formerly appreciated. The yields are not only vitally influenced, but the longevity of the plants and their vigor and hardiness, are greatly affected by the frequency of cutting at various periods of growth.

At the Kansas experiment station, a trial for eight years has shown greater yields from four cuttings taken annually in the full bloom stage than from five and six taken just before blooming began. At the Wisconsin station, in a three year trial with three varieties (Grimm, Imported Turkestan, and Kansas Common), two annual cuttings, taken when the alfalfa was in full bloom, have yielded over a ton more of cured weed-free hay per acre than three annual cuttings taken on and before the plots were in tenth bloom.

In both Kansas and Wisconsin trials, the more frequent cuttings at early stages of growth compared with less frequent cutting at more mature stages have resulted in (1) a gradual thinning of the stand;

[1]Published by permission of the Director of the Wisconsin Agricultural Experiment Station. Paper read as a part of the symposium on "The Forage Problem" at the meeting of the Society held in Chicago, Ill., November 12, 1923.

[2]Professor of Agronomy, Wisconsin College of Agriculture, Madison, Wis.

(2) a reduction of the vigor of growth, and (3) heavy encroachments of weeds and grasses.

From the practical standpoint, the greater yields from the more mature alfalfa has the additional advantage of reduced labor costs occasioned by a lessened number of cuttings. In a northern state like Wisconsin, the later cutting of the first crop is of importance in escaping the usually rainy period of the fore part of June. To offset these advantages, the coarser quality of hay is a factor to be considered. The Kansas station has found that hay cut at the full bloom stage contained 15.4% protein compared with 16.5% and 17.5% protein for the tenth-bloom and bud stages. Accepting these figures, or accepting the analyses in Henry & Morrison's "Feeds and Feeding," the yields per acre of protein, or digestible protein, or total digestible nutrients, is considerably higher for the full bloom cuttings in Wisconsin. There are times when the first crop, especially of older stands, may grow so rank and coarse that earlier cuttings may be essential, even though it may prove somewhat injurious to succeeding growths. Generally, however, the first crop of a one-year old seeding or the second crop of alfalfa of any age can be cut in the full bloom stage without serious impairment of quality. Where alfalfa is grown in short rotations, as is not entirely uncommon on the smaller farms in the dairy districts, permanence is not desired and three and sometimes four cuttings annually, at early stages of growth, may be advisable. For permanence, winter resistance and largest yields, however, cutting near or in the full bloom stage is becoming more and more an accepted practice.

Clipping Crown Shoots of Alfalfa Not Injurious

For many years, the time for cutting of alfalfa has been based on the appearance of the new crown growths or shoots of the succeeding crop. This has generally meant early cutting. It was formerly held that clipping these shoots, as a result of delayed cutting, was injurious to the alfalfa. This has not been true either in the Kansas or Wisconsin trials. At Wisconsin, the most vigorous, the thickest and most winter-resistant plots at the close of the third years' trial are the series which were cut twice annually in the full bloom and seed pod stages when many of the crown shoots were from two to eight inches in height before cutting was begun.

Possible Explanations

Just why early cutting for a period of years is injurious to the growth and stand of alfalfa is a problem which is by no means solved, but one which offers a splendid opportunity for agronomic research and many practical applications of the findings.

Waters,[3] in a five year trial with timothy, found "that early cutting thins the stand and that this thinning can be avoided by allowing plants to mature." This work was done more than twenty years ago, yet the same general response prevailed with timothy that has more recently been found in cutting trials with alfalfa.

The writer will make no attempt at a complete explanation other than to venture a working hypothesis which has been formulated as a result of experiments that are being carried on jointly with the Department of Applied Botany of the University of Wisconsin, and the results of many investigations in the past with various horticultural crops. Such experiments indicate the great importance of stored food materials in relation to the amount and type of growth which can be made by the plant. With a fleshy-rooted perennial plant like alfalfa, it appears reasonable to suppose that these reserves are largely stored in the root and crown. In the early period of top growth, much of this reserve is utilized in "structural" development or in building the "frame work" of the stems and leaves, before such structures are able to manufacture sufficient food material for their continued development. As is well known, healthy roots of alfalfa transplanted into pure quartz sand and placed in a dark room at growing temperatures will produce whitish stem and leaf growths of eight to sixteen or more inches. The growths are a result of the translocation and metabolism of a part of the reserves.

In the field growth, it is most likely that something similar to this occurs. The root reserves are utilized for building material and to some extent as a source of energy until the plant becomes sufficiently developed not only to manufacture its own food requirements for growth but gradually to produce food in excess of its immediate needs. It is then when root storage probably begins. It is not possible to state the exact time or stage of growth in alfalfa when this occurs, for this may vary widely under different environmental conditions. Ordinarily, with alfalfa one year old or older, it appears, from tests made so far, that when blooming starts the plant has reached a stage where it is producing food in excess of its present needs and storage for future growth is begun. A marked acceleration in root storage probably occurs with the gradual approach of maturity, for the blooming period is usually one of great activity in the elaboration of plant food. This is illustrated by experiments showing that from the flower bud stage to full bloom—a period of about three weeks—alfalfa will often double its dry weight. Since root storage is probably

[3]Waters, H. J. Studies of the timothy plant, Parts 1 and 2. Mo. Agr. Expt. Sta. Res. Buls. 19 and 20, 1915.

not well advanced at the beginning of this period and since root reserves are rapidly utilized in the early vegetative stages of the plant's growth, it is obvious that with alfalfa cut very early and very frequently, there will follow a gradual exhaustion of the reserve materials. This may cause a marked reduction in the vigor of the succeeding growths or actual death of some of the plants. In fact, four cuttings at very early vegetative stages with two-year old Grimm and Turkestan alfalfa at Wisconsin, in 1921, caused almost a complete loss of stand and a yield of only 1.1 tons of hay an acre, as compared with no reduction in stand and a yield of 4.3 tons an acre for two cuttings in the full bloom stage. What transpired here in one growing season is more gradually occurring in the cutting stages of the bud, tenth bloom, full bloom and seed pod plots.

Physical evidence of root exhaustion is quite clear from root measurements made at Wisconsin, where it has been found that the plants receiving exhaustive cutting treatments have roots only about half the size and weight of those which have been cut less frequently in mature stages. Investigations are now under way which give promise of more definite information as to the chemical nature of these root reserves.

Should the above assumptions hold true, the lessened vigor, diminution of stand, and consequent lower yields from early and frequent cutting of alfalfa may be explained in part as follows:

1. Lack of sufficient root reserves for normal growth or an exhaustion of the reserves sufficient to cause actual death of the plants.

2. Lessened absorbtive capacity of plants of the elements of soil fertility.

3. Competition from encroaching weeds and grass growths due to lessened vigor of plants and thinning of stand.

4 Greater susceptibility to winter-killing of plants with low food storage.

The clear cut responses of alfalfa to various cutting treatments make this plant very valuable as a medium for initial investigations on root reserves. Undoubtedly there are other perennial plants where similar responses might obtain and with similar practical applications. A better understanding of the chemical and biological nature of root reserves, their utilization and deposition, may well prove significant in the improvement of some of our field practices, such as the proper maintenance of our hay crops, pastures and lawns, the eradication of certain weeds, and the solution of many of our winter-killing difficulties.

D. LEGUMES FOR ACID SOILS[1]

CHAS. F. LEACH[2]

I consider this opportunity to address you as the greatest honor of my life. I fully realize that every program should contain a comedy number and yet, while my paper may be amusing, I hope you will also find it interesting.

I am much embarrassed; not by the overwhelming erudition here assembled but because I do not speak your language and I fear you may misunderstand some of the words I will use. Therefore, to make my meaning perfectly clear, I ask the privilege of defining some words and expressions that I think do not always mean the same thing to all men.

I will speak of acid soils; by which I mean any soil that will not effervesce when hydrochloric acid is added and I do not mean soils that are sour because air has been excluded by poor drainage or otherwise. In other words, in speaking of acid soils I mean all well drained soils deficient in lime; most of which are really neutral.

I will speak of poor soils and worn out soils, because they are handy terms and not because I believe that, broadly speaking, there are any such things as poor or worn out soils in America. This belief is the product of my experiences on many of the so-called unproductive soils of the eastern part of the United States, and such of you as have never farmed in the Coastal Plains do not know anything about poor soil.

Professor Whitney has long since shown that all of our soils contain sufficient mineral plant food to last for many generations and I believe that I have amply demonstrated on Cherokee Farms that there are many valuable, but little known, deep-rooted plants that have the power to find and use and make available to the shallow rooted plants enough plant food to produce profitable crops until old Gabriel blows his trumpet. Professor Whitney found all soils equally fertile; what I want to tell you is that all soils are equally productive.

If it is the object of this symposium to stimulate discussion, I fancy I have contributed my share in that last statement.

I will speak of the acid-soil legumes. In doing so, I will mean all

[1]Paper read as a part of the symposium on "The Forage Problem" at the meeting of the Society held in Chicago, Ill., November 12, 1923.

[2]Manager of Cherokee Farms, Monticello, Florida.

legumes known to me except alfalfa, sweet clover and red clover. At the same time, I want it understood that I know that alfalfa, sweet clover and red clover will grow and flourish on some compact and naturally well drained soils that are distinctly acid without the addition of a pound of lime. In fact all of these legumes are now growing on Cherokee Farms where the soil has not contained a trace of lime since 1857. I make this startling statement on the highest scientific authority which you will find in a bulletin written by one of your most distinguished members. That bulletin was first published many years ago and republished in 1920.[3] As far as I know, the statements in that bulletin have never been challenged and it was sent to me this summer by its distinguished author as the last word on the subject of lime.

As I see it, a great mistake has been made in considering the top six or seven inches of the land as the soil. That is only the crust, the real pie is far below, and most of the legumes and indeed a majority of cultivated plants get their food far below the crust. The soil below the crust contains practically inexhaustible stores of plant food and, except where solid rock or water lies too close to the surface, these inexhaustible stores of plant food, can be used and are used by many deep-rooted legumes, grasses and plants which in dying, or when their tops decay, add this subterranean plant food to the top soil and thereby make it available to the shallow-rooted plants. Nature devised this method of renewing the productive capacity of the top soil many years before Professor Leibig discovered the "French chef" method of supplying plant food artificially. The French chef, when given a large number of ingredients, brought from the four corners of the earth, can prepare some very tasty dishes; but the good wife of a common bread-and-butter farmer can set before you a more wholesome and satisfying meal made from things raised right on the farm.

The power of legumes to take nitrogen from the air has been the great outstanding value ascribed to them. I think it has been greatly overemphasized. As most legumes are deep-rooted plants and have great feeding powers, I am persuaded that their most valuable function is to gather from the subsoil; digest and deposit on the surface all of the minerals, including lime.

Many theories about the planting and culture of legumes have been universally accepted which never had any foundation in fact. One of the most harmful of these theories, because it has deterred thousands of farmers from planting legumes of any kind, is the

[3]Truog, E. Testing soils for acidity. Wis. Agr. Expt. Sta. Bul. 312, 1920.

statement, found in all bulletins, books and articles on the subject, that sunlight is fatal to legume bacteria. Prof. Albrecht has shown beyond question that this is not true in the case of soy beans and red clover and long since I found that alsike, red, white, crimson, sweet and bur clovers, black medic and vetch can be inoculated and sowed right on our close-cropped Bermuda grass pastures, or on top of plowed land, and lie there exposed for months to the brightest sunlight without affecting the bacteria.

Another theory which is universally accepted as proved and settled, is that the bacteria peculiar to the *Medicago* family of legumes cannot live in an acid soil; yet it has long been known that bur clover thrives in an acid soil with its mass of roots covered with nodules and that black medic grows wild, in acid soils, from the Gulf to the Great Lakes. Professor Stokes of the Florida station, has found that Hubam clover grows quite as well in the lime-deficient and acid soils of central Florida as it does in the same soil when heavily limed. Annual and biennial white sweet clover are now growing on Cherokee Farms and alfalfa, two years old, is growing there vigorously, in soil distinctly acid.

The truth is that these bacteria are not "Calciphiles" and don't care a hoot whether the soil is acid or alkaline. The fact that some of the legumes on which these bacteria feed do not thrive in some soils that are acid has been well established, and it has been assumed that the ordinary organic acids inhibit their growth. My own observation leads me to believe that Whitney's theory of toxic organic matter deserves more consideration than has been given to it. It may be quite possible that toxic organic matter may remain inert or slowly soluble until some crop, like green rye, cowpeas, beggarweed, peanuts, vetch or serradella, turned under furnished the necessary catalyst. Certain it is these crops (when well chopped up and turned under green), do work a transformation in unproductive soils, but often they do not show any benefit to succeeding crops when turned under ripe and dry.

Pieters has shown, in his valuable paper on "Green Manuring," that, on some soils, green rye turned under produces a larger increase in succeeding crops than any legume with which it was compared. But I have found that beggarweed not only grows and thrives on soil where neither rye, cowpeas or any other crop, including weeds, could grow, and when turned under makes that soil produce heavy crops that just faded away before the beggarweed was grown. Yet beggarweed contains nearly as much mineral matter and eighty

percent more phosphorous than alfalfa, when grown on this apparently barren and unproductive soil.

Another theory that is just now very popular is that the amount of mineral matter, especially lime, contained in forage plants depends on the amount of those minerals in the soil in which they grow. The types of soils on Cherokee Farms are classed as lower in lime, phosphorous and potash than are any generally cultivated soil types in the United States; yet we grow heavy crops of Kudzu, beggarweed, serradella, velvet beans, cowpeas, vetch, crimson clover, peanuts, bur clover and black medic, without adding a pound of lime to the soil; and half our land has never known fertilizer of any kind. As shown in the accompanying Table, peanut hay, black medic, cowpeas and crimson clover contain more phosphorous and lime than alfalfa or sweet clover. Beggarweed contains eighty percent more phosphoric acid and nearly as much lime as alfalfa; and serradella contains nearly twice as much mineral matter, exclusive of potash, as alfalfa. White clover contains more phosphorous and as much lime as red clover; and alsike nearly twice as much phosphoric acid and more lime.

TABLE I.—*Pounds of minerals (exclusive of potash) in 1000 pounds of hay.*[a]

	Ash	Phosphoric acid	Other minerals except potash, mostly lime	Soil adaptation
Bermuda grass	75	4.0	50.4	Poor acid soil
Kentucky blue grass	75	5.4	48.0	Calciphile
Crab grass	80	9.0	40.1	Acid soil
Timothy	49	3.1	33.3	
Serradella	123	10.3	97.6	Poor acid soil
Black Medic	109	5.7	95.2	" " "
Peanuts (hay only)	90	6.3	59.7	Calcifuge
Alfalfa	86	5.4	57.3	Calciphile
Sweet clover (white)	72	6.6	52.8	"
Red clover	71	3.9	50.8	"
Alsike Clover	83	7.0	58.6	Acid soil
Crimson Clover	88	6.1	59.8	" "
White clover	80	5.2	54.8	" "
Cowpeas	110	9.6	59.1	Calcifuge
Soy beans	86	6.8	55.9	Acid soil
Beggarweed	84	9.4	46.7	Calcifuge

[a]Adapted from data in Henry and Morrison's "Feeds and Feeding."

The wonderful ability of Kentucky bluegrass to produce bone in the livestock pastured on it has been ascribed to the fact that it grows on a limestone soil, and it is cited as the outstanding and historical example of the benefits conferred on livestock by lime in a forage plant. Yet Bermuda grass, growing on soil containing less lime and phosphorous than any arable land in the United States,

contains more lime than Kentucky bluegrass; and poor old crab grass contains sixty percent more phosphorous. Crab grass and Bermuda grass thrive so well on Norfolk and Orangeburg soils that they often become a pest; yet these soils, which predominate in the Coastal Plains and the cotton belt, contain but 520 pounds per acre-foot of phosphorous and 1400 to 1800 pounds of calcium as against nearly 4000 pounds of phosphorous and 44,000 pounds of lime in the Hagerstown clay.

What I mean to say is that the idea that the amount of mineral matter in all forage plants is controlled by the amount of minerals in the soil is a pure myth; and that it is necessary to add vast quantities of lime and phosphorous to a soil to grow forage that will furnish the necessary minerals to livestock is a delusion. It is possible that that statement may cause some discussion and again it is possible it will appear to you too ridiculous to warrant comment.

Lime and fertilizers may be a short cut to the raising of some legumes and increasing temporarily the productiveness of some soils; but the experience of the past thirty years, the declining crop yields and the present condition of agriculture indicates that the lime, legumes and phosphate theory of permanent soil fertility has not as yet, for some reason, accomplished its purpose.

One of the greatest of the poor land, acid-soil legumes is the velvet bean. Its greatest value is the fruit it bears, but it has an almost equal value as a soil improver, for it grows on very poor, acid soils and it is not benefitted by lime or fertilizer. Years ago, Dr. Piper rendered to the entire south a very great service by promoting the production of earlier and better varieties of velvet beans; and recently Professor Morse has really given vast potential wealth to his country by developing the Arlington bean; which will grow on poor soil anywhere that dent corn will mature. I said "poor soil" advisedly, for the velvet bean, the peanut, beggarweed, serradella and Kudzu are essentially poor-land crops. The velvet bean, peanuts and beggarweed will not produce their fruit, or at least mature it, on land rich in nitrogen.

The Arlington bean is well worth your careful study, for I believe that on many soils in the North it will be found much more valuable than the now popular soybean. And the Spanish peanut, when grown with beggarweed on poor, friable soils, produces a combination forage and feed crop of greater value than soybeans, and because of their deep tap roots and immunity to organic poisons they are more valuable as soil-builders and soil-renovators.

I do not expect the distinguished educators here assembled to take

this paper very seriously,—*now*. I am a very ignorant man when judged by your standards, and I know I have been presumptuous to invade your field of labor. I thank you for your courtesy and forbearance with my vagaries.

2. HAY CROPS

E. CLOVER PROBLEMS[1]

A. J. PIETERS[2]

RED CLOVER AS A GENERAL FARM CROP

A discussion of the problems connected with the culture of as old a crop as red clover presupposes: first, that the crop is one of importance, for if it were not the problems would not be of sufficient interest to warrant a discussion at this time; and second, that the culture of the crop is being attended with certain difficulties or that the crop is not being grown as widely as its general characteristics would seem to warrant.

Red clover is unique in being by far the best dual-purpose rotation crop known today. It is one of the standard hay crops of the northeastern part of the United States, its competitor and companion being timothy. Alone or in combination these two crops yield upwards of ninety percent of all the hay produced in the territory east of the western boundaries of Minnesota, Iowa and Missouri, and north of the southern boundaries of Missouri, Tennessee and North Carolina.

As a hay crop red clover does not, of course, take the high place occupied by alfalfa which is in a class by itself. With the exception of alfalfa, however, red clover has perhaps no successful competitor as a valuable protein-producing hay crop and in addition red clover possesses value as a rotation crop.

Red clover is of special importance in maintaining the productivity of the soil. As a hay crop it might be successfully replaced by various other legumes, especially soybeans, but as a combined hay and soil-improving crop soybeans can not pretend to rival red clover. Red clover has about thirty percent of its organic matter under ground, soybeans only ten percent; if soybeans, or any other annual legume for that matter, are cut for hay and the crop removed, the soil will be poorer in nitrogen than it was before the crop was grown.

[1]Summary of discussion presented as part of the symposium on "The Forage Problem" at the meeting of the Society held in Chicago, Ill., November 12, 1923.
[2]Agronomist, Forage Crop Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C.

Brown of Iowa has shown that a crop of red clover often takes more nitrogen from the atmosphere than is removed in a hay crop. A successful crop of red clover yields not only a hay crop but also a considerable amount of second growth, which can be utilized for grazing, for green manure, for a seed crop, or for additional hay, as the circumstances may seem to indicate.

Clover Culture Decreasing

During the period between the census of 1900 and 1910, the acreage devoted to red clover alone in the northeastern quarter of the United States declined by approximately forty-two percent; this decline was, of course, much larger in some sections than in others, but that figure was about the average. During the period between 1910 and 1920, there was an increase in acreage of clover, but the percentage of increase during the second decade did not equal the percentage of decrease during the first, so that in 1919 the acreage of red clover was still considerably below that of 1899, while the acreage of cereals in such areas as the east north Central States, and in Minnesota, Iowa and Missouri, had slightly increased.

The fact that the acreage of red clover has decreased can also be brought out by a study of the production of red clover hay as compared with that of all tame hay as given by the census of 1900, 1910 and 1920.

Table 1.—*Showing the percentage of the acreage in all tame hay that was in clover alone in 1899, 1909, 1919.*

	1899 Percent	1909 Percent	1919 Percent
New England	0.47	0.43	0.76
Middle Atlantic	5.30	1.98	2.69
Delaware, Maryland, Virginia, West Virginia	13.67	5.80	8.33
Kentucky, Tennessee	21.38	14.90	14.66
Eastern North Central	17.68	8.78	10.45
Minnesota, Iowa, Missouri	7.16	4.91	7.43

It will be observed that only in the New England States, where the proportion of red clover is very small anyway, and in the extreme western part of the area under consideration, has the relative proportion of red clover been maintained; in all other sections the percentage of tame hay that consisted of red clover was much smaller in 1919 than it was in 1899.

The question as to what percentage of cultivated land should be in legumes is often referred to in experiment station literature. There is no way to give an exact answer to this; but if it is assumed that the standard rotation in the northeastern part of the United States is a four-year rotation of corn, oats, wheat, and clover, then

it is evident that on the average about twenty-five percent of our cultivated lands should be in clover. The workers at both the Illinois and Michigan stations have expressed the view that one-fourth of cultivated land should be in legumes each year. However, it must be borne in mind that all legumes will not accomplish the same result in maintaining soil productivity. It is interesting to note in this connection the area which is actually in clover. Table 2 shows the percentage of the acreage in all harvested crops planted to timothy and clover and to clover alone, according to the census of 1919.

TABLE 2.—*Showing percentage of acreage in all harvested crops that was in timothy and clover and in clover alone in 1919.*

States	Timothy and clover	Clover alone	Clover and one-half timothy and clover acreage
	Percent	Percent	Percent
New England	39.00	0.52	20.20
Middle Atlantic	26.00	1.10	14.10
Delaware, Maryland, Virginia, West Virginia	8.00	1.35	5.55
Kentucky, Tennessee	3.13	2.30	3.86
Eastern North Central	9.50	2.00	6.75
Minnesota, Iowa, Missouri	6.20	.97	4.07

If one-half of the timothy and clover percentage be added to that of clover alone, on the theory that in the average mixed field red clover will be the preponderating crop during the first year, and timothy during the third year with a fairly even distribution of both during the second year, it will be seen that nowhere, except in the New England and Middle North Atlantic States, does the proportion of acreage of all harvested crops which is in clover equal seven percent. This falls very far short of the twenty-five percent which is theoretically desirable.

It has been shown that clover is an important crop and that there is something wrong with it. What is wrong? The work of the experiment stations in the northeastern part of the United States has shown conclusively that in a majority of cases as good crops of clover as were ever raised can be grown, if the farmer will use lime or phosphate or, in occasional instances, potash in order to make the soil suitable for clover. From this standpoint, the problem is no different from that facing the grower of any other crop. If the soil does not contain the necessary elements, or if it is in an unsuitable physical condition, the clover will not thrive, but will either die outright at some stage of its existence or will make an unsatisfactory growth. It would seem that this aspect of the problem does not

require much more detailed experimental work to establish the general proposition that, over most of the area in question, lime and phosphate, alone, or in combination, will solve most of the difficulties with clover. Just which one is necessary, or just what combination will be best; is a local question to be determined by the farmer with the help and advice of the county agents, the extension service and experiment stations.

Adaptability of Seed

Another phase of the matter which has come to notice, especially in recent years, is the effect of using seed of adapted or non-adapted strains of red clover. Some twenty years ago, a series of tests was inaugurated by the U. S. Department of Agriculture to study the value of different strains of clover, but owing to a change of personnel these studies were not carried far. However, they were taken up again in 1916. Although interrupted by the war, this work has been carried on more or less steadily since 1916. From these studies, it has become perfectly clear that some seed, which is imported in considerable quantities, will produce satisfactory stands during the summer, but that all plants of these stands will probably disappear before the following spring. The seed from Italy has been found to produce plants which are not reliably hardy in the colder sections of the Ohio and Great Lakes area. This statement does not mean that the stand will always be entirely destroyed, although this has frequently proved to be the case, but that in every case the use of this seed is risky. With the single exception of the 1922 and 1923 trials at the Pennsylvania station, there has been more or less loss of stands on the plots on which Italian seed was used, in every cooperative trial and in every year while this work has been going on.

The Disease Factor

The disease factor is closely associated with the question of strain. In using the term disease factor, reference is made especially to the anthracnose caused by *Colletotricum trifolii*, which, as is well known, has been so disastrous to clover culture in Tennessee and which was studied especially by Bain and Essary. This disease has been quite serious on the clover plots at the Arlington Farm, where the disease destroyed nearly or quite 100% of the stand on the plots sown to Italian and German seed, and made very heavy inroads on the stand of the plots sown to Bohemian, English, French, and Polish seed. Plots seeded to Chilean seed also suffered, but not nearly as much as the other plots. Plots seeded to Oregon seed lost more than 90% of the stand, and plots seeded to Idaho and Minnesota seed also suffered

to a certain extent. The only plots which showed approximately no injury were those seeded to the Tennessee disease-resistant strain and to some seed purchased in southwestern Ohio, the exact origin of which is not known beyond the fact that it was Ohio grown.

How far this disease referred to is responsible for the loss of stands of red clover is not known, but there is considerable evidence to indicate that this factor is much more important in the states south of the Ohio than has been suspected. Whatever the facts may be in this regard, it is quite evident that there is a considerable difference in susceptibility between various strains, and that the Italian strain is particularly susceptible to this disease.

This problem of the proper strain of red clover is, therefore, one of the outstanding problems with which we have to deal, and it is hoped that those connected with the work in the U. S. Department of Agriculture may pursue this line of investigation until some definite and helpful solution is found.

2. HAY CROPS

F. SWEET CLOVER AS A HAY CROP[1]

H. L. Walster[2]

Sweet clover,[3] once legislated against as a noxious weed, has now established itself as an agricultural crop to a greater or less extent in almost every state in the Union.

Two environmental conditions only seem to limit its even more extensive spread, namely, lack of carbonate of lime in the soil (or of available calcium) and poor drainage. Even in the latter case, however, it seems to be able to withstand more poor drainage than can most legumes. Sweet clover's sudden popularity may be attributed to the ability of the plant to thrive under a wide range of soil textural conditions, to withstand considerable concentrations of salts in the soil, and to withstand both drought-injury and cold-injury.

The crop offers usefulness as a general forage crop, utilizable as hay, pasture or for soil improvement. It seems to be the concensus of opinion of investigators throughout the United States that the

[1]Paper read as a part of the symposium on "The Forage Problem" at the meeting of the Society held in Chicago, Ill., November 12, 1923.

[2]Agronomist, North Dakota Agricultural Experiment Station, Agricultural College, N. D.

[3]This discussion of sweet clover is limited to a consideration of the two biennial species, white sweet clover (*Melilotus alba*) and yellow sweet clover (*Melilotus officinalis*).

crop has its widest usefulness for soil improvement; that it is rather generally useful as a pasture crop, particularly for cattle, horses and sheep, but not well suited for hogs; and that its usefulness for hay is extremely limited.

Any forage crop, as well as any other crop for that matter, to be available for general use must fit into the general scheme of farm management. Sweet clover, possessing as it does certain weed characteristics, has limitations in this respect. Five habits or qualities of the sweet clover plant give to it the following "weed" characteristics: (1) its abundant seeding habit; (2) its persistent seeding habit; (3) its readily shattered seed pods; (4) its hard seeds; and (5) its highly dormant very persistent winter buds.

The characteristics of the sweet clover plant which have just been enumerated require that due attention shall be given to the possible danger of the crop appearing as a weed where not wanted, especially whenever seed is grown or permitted to ripen, as under pasturing. Under the climatic conditions prevailing in the Northern Great Plains, large quantities of organic matter that may be plowed under do not readily decay. Neither is it ordinarily easy to bring about the complete sprouting of all weed seeds that may be in the ground. Where milder, shorter winters prevail and with a longer growing season, biennial sweet clover may be seeded as early as January in Texas, or in February and March in Ohio and Indiana on a winter grain crop, and after the removal of the winter grain crop, a luxuriant growth of the sweet clover will be produced, which can be utilized for hay. This hay crop will be made at a time of the year when dry weather may ordinarily be expected. The crop can then be allowed to grow through the winter and be plowed under early the next spring. It will have had an opportunity to make considerable growth the next spring before being plowed under for corn. An occasional farmer in Ohio, Indiana or Illinois has reported difficulty from the volunteering of sweet clover plowed under in its first year of growth, but this rarely happens.

On the other hand, the farmer in the Northern Great Plains usually seeds his sweet clover in a grain crop in April or May. If the grain crop is removed and a period of droughty weather ensues, the sweet clover makes but little growth and, if plowed under in the fall of its year of seeding, will almost invariably thrust sprouts from its winter bud through the furrow slice the next spring. The farmer may decide to wait unt l the succeeding spring to plow under his sweet clover. He will find that he has to delay his spring plowing until the sweet clover has made a growth of three to six inches, if he is to escape the

danger of volunteering sweet clover plants arising from the winter bud.

In the Northern Great Plains states, sweet clover seems to be finding its greatest usefulness as a pasture crop. Even when used as a pasture crop, seeds mature unless extremely early fall plowing is resorted to in order to kill the plant before it reaches normal maturity.

Sweet Clover as a Hay Crop

Good hay crops have certain characteristics, among which are: a high percentage of leaf; fine stems; a low percentage of crude fiber; a high percentage of protein; and a physical and chemical makeup which permits rapid curing with the minimum of mechanical loss and the minimum danger of mechanical or chemical loss due to the exigencies of the weather. The following statements may be made concerning the sweet clover plant with respect to some of these characteristics. In the northern zones of agriculture at least the following objections are urged against sweet clover as a hay: (1) the first crop is ordinarily ready for cutting when the weather is unsettled, (2) the crop cures very slowly, the leaves drying out very much faster than the stems with resultant loss of leaves; (3) growth is too rank and too coarse to make good hay.

Zavitz[4] has pointed out that with sweet clover the leaf makes up about fifty percent of the weight of the hay, these estimates being based on plants ranging in height from 40 to 54 inches. He calls special attention to a special strain called Albotrea, which has a somewhat larger percentage of leaf, but which does not appear to be a high-yielding strain. Some of these leafier varieties of sweet clover may replace the coarser, woodier varieties now commonly grown, provided their yields can be brought up. Zavitz does not indicate the rates of seeding which were used in his trials. It is evident that the rate of seeding influences the leafiness of the plants, particularly with such a plant as sweet clover. Not only will the rate of seeding influence the leafiness, but it will also influence the fineness of the stem. Observations with respect to this relation are badly needed.

The high water-content of the sweet clover stem and its slow rate of drying out apparently make it an excellent medium for the growth of certain molds. During the winter of 1922-23, many cases of cattle poisoning were reported in Minnesota, North Dakota and Canada, which were attributed to the feeding of spoiled sweet clover hay. The causal relations have not been worked out. How-

[4]Zavitz, C. A. Sweet clover as a farm crop, Ontario (Canada) Agr. Col. Bul. 283. 1921.

ever, the poisoning, with the resultant death, has been produced experimentally on cattle and other animals. During the past winter, the writer sent a questionnaire to some of the oldest growers of sweet clover in the United States in the states of Ohio and Iowa, and obtained from them only one instance of report of the death of cattle due to the feeding of moldy sweet clover hay. No trouble has been experienced when the sweet clover hay fed has been bright and free from mold.

When a late hay crop can be made from the first year's growth of sweet clover, as is the practice in the northern part of the corn belt and further south, apparently a fairly good quality of hay can be made. Under conditions such as obtain in the Northern Great Plains, it is not ordinarily possible to take a hay crop the first year, but instead the growth in the second year is relied upon. This growth usually comes on so fast that the hay crop produced is too coarse and stemmy. When sweet clover is grown on very fertile soils well supplied with moisture, it is no unusual occurrence to find the crop four to five feet tall just as the first flower buds are beginning to form. It is apparent, therefore, that the usual recommendation "to cut when coming into bud stage" involves the harvesting of coarse material which will cure slowly and at best make poor hay. In view of these facts it would appear that early clipping of the crop back to a seven or eight inch stubble, when the plant has reached a height of from twelve to eighteen inches, will provide for a renewed growth of finer stems and will delay the first hay crop from three to four weeks, thus throwing the haying over into a period in which more favorable weather is likely to occur. Clipping back should be to a high stubble in order that renewed growth from the axils of the leaves may occur.

Yellow sweet clover (*Melilotus officinalis*) has somewhat finer stems and makes a somewhat shorter growth than white sweet clover. It is also earlier in the spring and matures in a shorter season, but does not yield as well as *Melilotus alba*. Yellow sweet clover is preferred by some farmers for hay making purposes, but it has not been as generally popular. Certain strains of yellow sweet clover are much more spreading than others; some yellow sweet clover grows as erect and as tall as any white sweet clover. Much work needs to be done in sorting out the different strains of yellow sweet clover.

Plant breeders have as yet given little attention to this new forage crop. It should be possible to improve both the white and the yellow biennial strains in many ways. Certain selections of

white sweet clover are notably earlier, shorter, and rather lower yielding than the ordinary types. Grundy County, or dwarf sweet clover, is an example of this type of white sweet clover.

Palatability and Digestibility of Sweet Clover

The green sweet clover plant contains a large amount of coumarin. Much of this is rapidly liberated during the drying of the plant. This substance imparts to the plants its peculiar bitter flavor and is probably the reason why many animals show varying idiosyncrasies in their appetite for the crop. In addition to this coumarin content, especially when the crop is being pastured, it must be borne in mind that this is a very soft feed and one on which ruminating animals do not readily chew the cud. The whole physiology of the utilization of sweet clover for pasture purposes by ruminating animals needs a general examination. Some animals when pastured on sweet clover make no gains for periods as great as a month or six weeks, whereas other animals begin to gain almost immediately.

When sweet clover is made into hay, some animals tend to reject it, although feeding trials have been reported where bright sweet clover hay seems to have been taken to just as voraciously as bright alfalfa hay. Digestion trials conducted with ruminants seem to place sweet clover hay on a par with alfalfa hay.

3. SOME SILAGE PROBLEMS[1]

R. A. Oakley[2]

The use of the silo has increased so greatly in the last decade that many valuable data on silage making have resulted from the cut and try experiences of farmers. Today, a study of the broad question of the silo in American agriculture leads directly to the conclusion that the problems relating to the use of the silo are chiefly plain economic ones rather than those of technical research. In these days, when the margin of profit in agricultural products is small and the chances for loss great, the farmer considers the matter of hired labor and other items requiring a cash outlay with unusual conservatism. The filling of the silo is by no means a cheap operation. Much labor is involved, and whether the harvesting of the silage crop and the cutting of the green material is done by machinery owned

[1]Paper read as a part of the symposium on "The Forage Problem" at the meeting of the Society held in Chicago, Ill., November 12, 1923.

[2]Agronomist, Forage-crop Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C.

by the farmer, or by a group of farmers cooperating, or is hired outright, the cost of making silageisaveryimportant item.

The economic problems relating to the silo are ones that will require some time to solve and the solving of them will be influenced by local conditions and will rest largely with the individual farmer.

As viewed broadly, today, it is quite apparent that the silo is an important and valuable adjunct to dairying, especially where dairying has commercial features. Silage has a beneficial influence on milk flow. It is also quite clear that the silo will help appreciably in the keeping of livestock on what are known as "dry-land farms," where the supply of cured forage produced in a given year is decidedly inadequate, and where it must be carried over from one year to another if livestock are to be maintained at all successfully. But just what part it will play in beef production, or in connection with the raising of livestock generally, where the raising of forage is not an acute problem, is not clear. It is obvious from the present indications that the livestock industry, unless possibly it be some intensive form of it, will not pay dividends on high priced roughage. Where silage falls into this class, and in many cases it does fall there, the use of the silo will naturally be limited.

It is quite generally believed that silage is a cheap forage. Silage is a convenient feed, but not a cheap feed. While it is true that a relatively small area of land will produce a relatively large quantity of roughage, provided corn, the sorghums, or some other coarse growing crop is raised, the difficulty lies in the cost of putting the crop into the silo. It has been suggested that labor saving machinery will be developed that will cheapen the cost of making silage. This may be possible, but there is nothing yet in sight that offers promise, and it is quite probable that new silage machinery, such as mechanical packers, even though much improved from what they are at present, or machines to cut the material at the time of harvesting, will add to the cost of silage making, rather than reduce it. Very broadly speaking, the farmer has already been over-sold on machinery.

Improvements in silo construction will contribute to the popularity of the silo to the extent that they lessen the cost of construction; but it is not likely that the cost of construction will ever be reduced materially, except as it may be reduced as a result of a general reduction of price levels. The development of the pit silo has helped, but has not revolutionized silo construction or the handling of forage. The conditions under which the pit silo can be used advantageously

are now quite well appreciated. Unquestionably, the pit silo will find a greatly enlarged field in the drier parts of the country.

As for the broad agronomic problems, to a very great extent these have been reasonably well cared for. It is clear in the minds of most farmers that tonnage is the first consideration in the selection of a silage crop. Naturally, corn has gained a place in the front rank generally where silos are used. Corn is an excellent silage plant. It has in its favor the ability to grow under a wide range of conditions, which makes it useful in almost every part of the country. It has the ability to produce a heavy tonnage of green matter and to make an excellent quality of very palatable silage. Corn has two competitors as a silage crop, sorghum and sunflowers: the first, an important one; the second, relatively unimportant.

In what may be referred to as the "sorghum belt," the sorghums generally exceed corn in tonnage yields. They make very high-grade silage; probably less valuable than corn, but very satisfactory. Furthermore, they remain in a suitable condition for silage-making for a much longer period than does corn. This is a distinct advantage. Sorghums do not make as palatable silage as does corn, and unless the rind of the stalk is split or crushed at the time of cutting, the short, hard pieces, one inch or more in length, are often refused by the animals. However, this is a matter that can be corrected by using the proper kind of cutter. Feeding tests of sorghum silage indicate it to be nearly as nutritious as corn silage, and experience of farmers support this conclusion.

Sunflowers have received a great deal of attention from the standpoint of their silage possibilities, but it is quite apparent now that they will never occupy a large field so long as corn and the sorghums can be grown with the success that now attends their culture. In the west, under irrigation, under most conditions sunflowers produce a larger tonnage than corn. There are also somewhat restricted areas of high altitude, and limited sections in the northern part of the United States, where they are likewise able to produce a heavier yield of green matter than does corn without irrigation. But sunflowers can hardly be said to be more drought resistant than corn, and everything considered, they fall far short of being a highly desirable silage crop. Difficulty has been experienced in some localities in making good silage from sunflowers, but this is not regarded as serious. Good sunflower silage is palatable; and Schoth[3] has found

[3]Schoth, H. A. Comparative values of sunflower silages made from plants cut at different stages of maturity, and the effect of salt on the palatability of the silage. *In* Jour. Am. Soc. Agron. 15:438–442. 1923.

that its palatability can be increased by the addition of salt at the time of ensiling.

There are a great many crops which can be used for silage making if occasion requires. In fact, it has been shown conclusively that almost any of our common herbaceous plants, including practically all common weeds, can be converted into good silage if their moisture content is not excessive. The problem then is not what will make good silage, but what will make cheap silage.

Excellent silage can be made from alfalfa. Carefully conducted palatability tests show it to rank next to corn, if not quite as high as corn, in favor with cattle. But alfalfa does not produce a sufficient tonnage to recommend its general use for this purpose. Sweet clover likewise makes good silage; less palatable, but probably quite as nutritious as alfalfa; but there is the same objection to it as there is to alfalfa. The opinion that seems to be somewhat prevalent that good silage cannot be made from alfalfa or sweet clover alone is erroneous. Excellent silage can be made from them without unusual care. This is generally true of the common legumes. The plants should be somewhat more mature than for the best quality of hay before they are cut for silage; otherwise, the resulting silage is likely to be too high in moisture, in other words, slimy. A tight silo also is highly desirable even though not absolutely necessary.

In cases of emergency, Russian thistle and other weeds may be used for silage. However, they are not to be recommended where reasonably good yields of corn, sorghum, or sunflowers can be obtained. In a very large majority of cases, weeds prove to be an expensive source of silage. Most farmers are well aware of this fact.

The opinion that the silo will help solve the hay-curing problem, by permitting the farmer better to utilize his rain-damaged hay, has not much support in practice. If wet weather comes on at the time of haying, conditions are usually such that farmers cannot get on the land with the necessary equipment to cut the crop for ensiling it, and the cost of making silage under such conditions is beyond the limits of its value. External moisture on green material, such as most hay plants, is inimical to the making of good silage. Little promise, therefore, is offered for the utilization of waste or wet, uncured hay as silage except in cases of extreme emergency.

The farmer has a problem, however, in the making of silage by the stacking of green material in open stacks. Excellent silage is made this way from canning factory refuse; and, in several cases, it has been reported that good sweet clover silage has been made by stacking the freshly cut sweet clover after harvesting with the binder. In

this connection, investigations are necessary to work out methods that can be depended upon for good results. Too frequently, hay or coarse green material stacked in this way molds or decomposes rather than ferments for good silage.

There is still considerable support for the recommendation that legumes be included with corn or other crops in the making of silage. This is a point that the farmer will have to solve very largely by cut and try methods. Offhand, it now appears that soy beans, for example, grown with corn or included with corn in the silo, do not add sufficiently to the value of silage to warrant their inclusion; or, to be liberal, their use is on the border line of economy. It is quite evident that good feeding tests are needed; and while it is not intended to indulge in criticism here, it is offered as a suggestion that in making feeding tests of silage in the future, silage should be the main feature of the ration, rather than an incidental one.

There is no doubt that silage can be kept in properly constructed silos for five or more years, in the drier parts of the United States. This fact is encouraging, since it bears directly on the possibilities of producing livestock profitably in connection with dry farming, where the growing of wheat and similar crops is too precarious to provide a dependable livelihood for the farmer, and where a supply of cured roughage must be carried over from good years to poor years.

Mechanical, construction or engineering problems relating to the silo are not pressing. However, if some good means could be developed for the making of a tight cover at a low cost, it would be a worth-while step. In fact, a tight cover is highly useful in making alfalfa or sweet clover silage. It is true that there is comparatively little waste in corn silage where no top is used and where the silo is covered only by the ordinary roof. But, in the future, it is probable that tight tops will be very advantageous in connection with modified methods which it is possible may obtain.

As for the critical-investigation problems, there is still much to be done in their solution. Some of these problems relate to the making of cheap palatable and valuable roughage from material low in feeding value, through the medium of the silo. There are some important points in this connection. If, for example, straw or similar roughage could be profitably converted into good silage, the practice would be a very useful one indeed.

Considerable investigation has been conducted in the matter of effect of temperatures on the making of silage. In Germany, especially, artificial heat has been used to influence fermentation changes. The investigators are aiming at what is called the making

of sweet silage, whatever its advantage may be. In this country, and elsewhere, studies of the effect of temperature have been conducted in which the rise of temperature has been brought about by filling the silo a part at a time and allowing the natural reaction, which is largely a process of oxidation, to develop heat. The heat thus produced is controlled by adding freshly cut material when the desired temperature has been sufficiently long sustained. Investigations are still being conducted with inocculents and activators. For the most part, these have consisted of substances added with a view of increasing bacterial activity. Some of them, however, have been added for the purpose of decreasing bacterial activity and some to act as condiments or flavorings to increase palatability. A minor point is to increase the keeping quality of silage. The chief object of the investigations of the problems relating to chemical and biological activities is to produce cheap, nutritious, and palatable silage from material that would otherwise, to a large extent, be wasted.

Most of the broad silage problems, as they appear today, may be stated quite briefly under the two headings, "farmers' problems," and "the critical investigator's problems." The farmer must decide for himself whether or not the silo can be used economically by him in his type of farming. If he is a dairy farmer, it is altogether likely that he will decide in the affirmative. If he is in a section of low rainfall where crop failures, even forage crop failures, are more or less frequent, it is probable that he will find the silo a valuable means of carrying over an adequate supply of roughage from years of abundance to years of scarcity. Some means of carrying over a sufficient supply of roughage from one year to another appears to be highly necessary if livestock is to be an important feature in such sections. But if the farmer is in the corn belt, or in other sections where the supply of cured forage is dependable, the economic advantages of the silo will depend very largely on the relative market value of corn as grain. If the price of corn is relatively high, the farmer will be inclined to reduce his herd rather than feed high priced roughage. Where silage is an expensive roughage, the farmer must decide to what extent he is willing to sacrifice economy for convenience.

The selection of crops for silage is a problem which the farmer has settled reasonably well for himself. Likewise, he has settled, pretty generally, the problem of the stage of maturity at which to cut silage crops in order to obtain the best quality. He will, as a matter of course, endeavour to cheapen the cost of making silage, and especially in the case of the pit silo, will endeavor to cheapen

the cost of construction. Doubtless he will experiment with the stack method, with a view to making it more satisfactory and more dependable. Furthermore, the farmer will, as he has always done, work out the most satisfactory rations of silage for the needs of his livestock. These are some of the lines the farmer's investigational activities will take.

The problems of the critical investigator are sufficiently numerous and important to engage his attention for an indefinite time. One of the most important, even though not the most likely of solution, is the making of a profitable and palatable silage from such waste products as corn stalks and straw by influencing bacterial activity, or by the addition of some relatively cheap common substances, or by any other simple method.

Another problem, which appears to be regarded by many investigators as important, has to do with the controlling of acidity of silage. Whether it is really important to control acidity is a point upon which there are few definite data. But it is a common belief however, that acidity is a highly important factor and many investigators are working actively upon methods of controlling it. Investigations involving the use of flavoring materials or condiments are worthy of consideration. There is still need of good feeding tests to determine, for example, the relative value of legumes in combination with corn or sorghum for silage. Attention may also well be devoted to open or stack silos, as they promise to lessen the cost of silage making. These are some of the more important problems for the investigator to attack.

The sole purpose of this paper is to set forth in a very general way the broad problems relating to silage and the use of the silo. The statements made are based upon studies conducted by the writer and Mr. H. L. Westover, of the office of Forage Crop Investigations, Bureau of Plant Industry, who are joint authors of a treatise on silage investigations now nearly ready for publication.

4. PASTURES

A. THE PROBLEM OF TAME GRASS PASTURES IN THE HUMID NORTH[1]

Lyman Carrier[2]

The following discussion applies to the humid parts of the northern

[1]Paper read as a part of the symposium on "The Forage Problem" at the meeting of the Society held in Chicago, Ill., November 12, 1923.

[2]Agronomist, Forage-crop Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C.

states that lie east of the one hundredth meridian and north of the cotton belt; and also to the moist meadow lands and irrigated pastures of the Rocky Mountain region, and the North Pacific coast west of the Cascade mountains.

In attacking the pasture problems, the investigator should recognize at the outset that he is dealing with a business which yields a very small margin of profit. The returns per acre from grazing are low. In some parts of the country, they are not sufficient to pay the fixed charges of taxes, labor and the cost of wintering the animals necessary to maintain the industry. While the returns are low, in most parts of the country the outlay is still lower. Pasturage is the only large supply of cheap feed in this country. There is also greater stability or certainty of income connected with grazing than prevails with other kinds of agricultural production.

If it is granted that half the feed consumed by livestock in the United States is secured from pastures, an estimate which all available statistics indicate to be conservative, then grazing lands assume an importance comparable to other major crops. Any method of general application which increases the returns from pastures by even a few pounds of meat, wool or milk per acre adds in the aggregate a large sum to the agricultural wealth of the country.

Seeding

One of the first essentials of desirable tame pastures is to secure a stand of plants which are adapted to the soil and climatic conditions of the locality. This appears so obvious that it scarcely seems worth mentioning; yet, as a matter of fact, many tame grass pastures have been seeded originally with plants not suitable for permanent grazing. Eventually, the better turf plants work their way in, but it would have hastened the formation of desirable turf if the best pasture plants had been given a start at the beginning. It has been customary in some cases, following an old English method, to seed a mixture made up of small amounts of seeds of a large number of species. Some seedsmen emphasize supposed virtues of their pasture mixtures by listing a large number of different plants, seed of which the mixtures are said to contain. There have been many tons of seed of such species as crested dog's tail, yellow oat grass, and meadow foxtail imported into the United States and sold in pasture and meadow seed mixtures; but it is a rare experience to find any of these grasses growing anywhere in this country.

There are only a few first-rate pasture plants which are adapted to any particular locality or condition. In the humid parts of the northern states, a greater variety of good plants can be grown than

elsewhere; but, even there, a mixture of not to exceed four or five species is all that should be seeded if the field is to be used primarily for grazing. On the rich lands, bluegrass, orchard grass and white clover will give the maximum amount of grazing. It is probably advisable to add some redtop to this mixture for the additional feed it will furnish the first two years after seeding. A mixture of redtop, timothy and alsike clover will stand more moisture than the other tame plants and should be used wherever the soil is wet and soggy.

Creeping bent is coming to be recognized as one of our best wet-land grazing plants. At present, there is no seed of the true creeping species on the market; but the sea-side strains produce seed quite freely along both the New England coast and in western Oregon and Washington, and it seems reasonable to believe that a supply of seed of these strains can be obtained if they are needed.

Requests for information in regard to plants suitable for pastures on poor soils are frequent. Unfortunately, at the present time, there are no known first-class grazing plants for such conditions. Japan clover, or lespedeza, answers this purpose fairly well in the South, and perhaps the recently introduced Korean lespedeza may play the same role in the northern states. For sandy soils, the fescues of the sheep's fescue type do fairly well, and furnish perhaps as much grazing as such soils are capable of producing. But thin, sandy soils are seldom satisfactory for permanent pastures.

The so-called "sour" soils will produce good pastures of Rhode Island bent, redtop, alsike clover and Canada bluegrass. This latter grass makes up a large part of the pasture herbage in the shale lands of western New York, Pennsylvania and Ohio. It is frequently found in quite large areas throughout the corn belt.

Fertilizing

On account of the small returns per acre from pastures, any attempts to increase production by the use of manures or commercial fertilizers must be planned on an economical basis. The writer has never seen a case where an application of fertilizer to a pasture has given an increased yield the first year which would justify the cost. It happens, however, that an application of barnyard manure and certain other fertilizing materials to pastures show beneficial effects which extend over a long period of years. The productive power of a pasture is a fairly constant factor. An application of fertilizer should, therefore, be looked upon as a permanent improvement. Given rich land at the start, a pasture will continue to produce for a great many years without any additions of plant food. But starting with a poor soil, the grazing will be poor equally as long. One of

the chief reasons why many permanent pastures on improved lands are so inferior is because the fields were heavily cropped, especially with cereals, before they were laid down in grass.

One of the best treatments to give to a pasture is to top-dress it with barnyard manure. Where manure is available no commercial fertilizer is necessary. In the absence of manure an application of some phosphatic fertilizer, as bone meal or acid phosphate, will usually cause a marked improvement in the turf. When these two materials are used on old turf, the effects are more pronounced from the use of acid phosphate than from bone meal. The acid phosphate is also cheaper, and it will encourage the growth of legumes, especially white clover, more than will bone meal.

Rate of Grazing

The proper stocking of a pasture is a matter of prime importance. This is a factor that is entirely under the control of the owner. The usual recommendations made in agricultural literature concerning this matter, so far as they apply to the grazing lands of the humid regions, are very misleading. One statement that has been repeated over and over again is "do not overgraze." A fairly thorough search of the literature of the world which deals with grazing fails to discover that "overgrazing" is looked upon with alarm anywhere in humid regions outside of the United States.

One frequently finds the term "proper stocking" used in the sense of having enough animals on the pasture to keep it properly grazed. The New Zealanders have an expression "even grazed" which appears to carry the meaning which is indicated in this country by "close grazing," that is, keeping the pastures grazed down until the ground is covered with a turf instead of letting the plants grow tall.

A study of the history of grazing lands in the northeastern part of the United States, making a comparison of the number of animals they formerly carried with what they carry now and of their former condition with their present condition, leads to the conclusion that more pastures in that portion of the country have been injured by under grazing than had ever been harmed by over grazing. The writer has seen thousands of acres of pastures in the eastern states, representing all conditions of stocking from complete abandonment to their full grazing capacity, and has never yet seen a pasture improve by taking stock off for a year or more.

Too many conclusions in regard to the handling of tame pastures of the humid regions have been drawn from experience gained in the bunch grass regions of the dry range country. A little study will show that these two conditions are not comparable. The grazing

plants of the humid region are either creepers, which do not need to form seed in order to spread and multiply, or they seed close to the ground, and so are not likely to be exterminated. More than this, these turf-forming pasture plants can not thrive in competition with the ordinary tall-growing weeds which invade a fertile pasture that is not closely grazed. There is a great need of much further study of the effects of different rates of grazing on the various pasture plants.

In the meantime, the fact that it is impossible to keep a good lawn without frequent mowing and fertilizing should not be overlooked. The nearer that a first-class lawn can be imitated in pastures the better the animals will thrive.

4. PASTURES

B. THE PROBLEM OF IMPROVING WESTERN RANGES[1]

JAMES T. JARDINE[2]

DEFINITIONS

Western Ranges, as discussed herein, include about 550,000,000 acres of wild pasture lands within seventeen western states, including the Dakotas, Nebraska, Kansas, Oklahoma and Texas, thence west to the Pacific coast.

Improving as here used means *improving forage production*, either in quantity or quality or both. It is not identical with increasing carrying capacity, since the latter includes much in the handling of the stock for efficient forage utilization rather than forage production alone.

CHARACTER OF LANDS

The 550 million acres of range lands vary in altitude from near sea level to perpetual snow. In type they vary from meadow of high carrying capacity to desert requiring 100 acres or more per cow. This great variation necessitates much regional and local study for most effective application of any general principle here stated.

CONDITION OF LANDS

Approximately 150 million acres used for grazing within National Forests and Indian Reservations are perhaps on an average 20 percent below maximum natural production.

About 250 million acres made up of unappropriated, unreserved Public Domain, coal, oil, phosphate and other reservations, unfenced

[1]Summarized paper read as a part of the symposium on "The Forage Problem" at the meeting of the Society held in Chicago, Ill., November 12, 1923.

[2]Director, Oregon Agricultural Experiment Station, Corvallis, Ore.

grant lands and private holdings, are probably on an average 40 percent below maximum natural forage production.

About 150 million acres in private holdings, mainly under fence, vary greatly in condition. As an average, perhaps 20 percent below maximum natural production is a safe estimate for this land.

Piper has estimated that the lands under consideration will sustain 15,114,000 animal units (cows) each year. Range improvement to maximum normal production would mean an increase of about 4,000,000 animal units—a very considerable item.

These estimates of acreage and condition are ventured merely to arrive nearer the problem. They may be wide of the mark. Endless discussion, however, would fail to establish the true status. The variations from the estimates given would be of little importance to the subject under discussion.

MAIN CAUSES OF RANGE DETERIORATION

Direct Causes

Many causes have contributed to bring about this deterioration of the western ranges. The main *direct causes* are generally conceded to be: (1) overstocking; (2) excessive grazing early in the growing season; (3) season-long, or continuous, grazing; (4) erosion; and (5) rodents.

Overstocking has been a common offense, and, for the most part, continuous. In part, it has been due to lack of reliable information on grazing capacity. In greater measure, it has been due to lack of appreciation of range, to lack of permanency of ownership, and to a general spirit of exploitation rather than of development of a sound permanent range livestock business.

Excessive grazing early in growing season. Until recent years, there has been little or no consideration of the requirements of the range plants for growth and reproduction. The main idea has been to get the stock out of the feed yard and off the cultivated areas. The plants have been weakened by removal of leaves as fast as they are produced, and injured by trampling. The total injury from these factors has been far underestimated.

Continuous grazing during the growing season, year after year. With the range as a whole not overstocked, choice species of grasses, constituting a large percentage of the whole, may be overgrazed and eliminated. The influence of this factor varies greatly with the composition of the vegetation and intensity of grazing.

Erosion is a factor which usually follows overgrazing.

Range destroying rodents have been a factor of importance in many localities.

Indirect Causes

The difficulties of removing these direct causes and the injury to the range have been increased by:

Inadequate, poorly distributed watering places for stock and *excessive unnecessary congregation* of stock at salting grounds, bedding grounds, and through herding.

Unfavorable growing seasons—delayed spring; unusual hot, dry summer; or year-long drought. It is difficult to anticipate the unusual season, and it is not easy to reduce the stock after the grazing season is on. Grazing capacity has not been adjusted to take full account of conditions over a *sufficient period of years*.

Open competition for free grass on public and many private lands has encouraged and, in many cases, has made necessary premature grazing, overstocking and continuous grazing. The man who pioneered, and put money into water and operating plant, has been forced to protect his investment by feeding off the grass before the "tramp herd" could get it.

Inability to plan and provide definitely for year-long needs. The 250 million acres of uncontrolled public domain, and interspersed grant and private lands, provide much of the spring, fall and winter range, taking the place, in whole or in part, of private pastures, stubble and hay in other sections. Lack of control has prevented the best use of these lands in organizing the individual livestock production unit[3] (one ranch) on the basis of year-long forage supply. As a consequence, there is constant necessity for departure from the grazing practice which is recognized as imperative to the improvement and maintenance of the range, in order to save the stock.

RANGE IMPROVEMENT

Range improvement must come mainly through better range management. In the light of present facts, range improvement will depend largely upon the extent to which the foregoing causes of range deterioration are removed.

Most areas will return to maximum natural production under wise use. Experiments and demonstrations by federal and state agencies, and the actual improvements of privately owned ranges have shown that the western range lands will regain approximately their maximum natural productiveness if they are proteced from grazing a few years, or used under grazing management which does not interfere seriously with the requirements of the vegetation for growth and reproduction. The improvement will require from three to perhaps fifteen years,

[3]Production unit as used herein means a ranch or farm used mainly for livestock production. It is intended to include harvested feeds and all pasturage.

depending upon seriousness of depletion, local conditions of soil, climate and plant species, and the extent to which harmful grazing is removed.

Outlook for range improvement by artificial seeding not encouraging. Range improvement by seeding with seed of cultivated plants and with seed of a limited number of native plants, has been tried in perhaps 1,000 seeding tests, representing fairly well the many combinations of soil and climate. The results indicate that improvement in this way is limited to small areas where soil and moisture conditions are far above the average. Such lands do not exceed, perhaps, one-half of one percent of the grazing areas within National Forests, are negligible on the open range areas, and constitute but a small part of private holdings. There are indications that turf-forming, or creeping pasture plants may extend the limits to less favorable areas. More work is needed along this line.

Introduction of new range plants has possibilities. Range improvement, beyond natural recovery of the ranges, depends upon finding plants of grazing value which will grow on the range lands and increase production. This possibility has barely been touched. *The great value of plants introduced into American agriculture warrants the hope, if not the assumption, that much could be accomplished for our ranges.* Search of foreign lands for valuable hardy species should be undertaken by the Federal Government without delay, and ample provision should be made for thorough testing of the introductions under range conditions. Assuming that valuable new plants are found, their effectiveness in improving the range will be governed a great deal by the extent to which better range management is practiced.

SUGGESTIONS

In a broad sense, the following problems and suggestions apply to all western range territory, yet they require local solution:

Range Improvement must be accomplished under grazing use. The ranges are a part of the year-long feed supply. Their use annually, therefore, is imperative to the livestock industry. Range improvement and maintenance must be accomplished under use.

Control of public domain imperative to improvement of 250 million acres, and important to better management on national forests and on much private land. Any marked improvement in the public domain, and interspersed private and grant lands, is impracticable under grazing use until legislation makes possible a practical system of control and management through private ownership, a leasing system, or a permit system similar to that in practice on the National Forests.

If proof is needed for this statement, the public domain in any far-western state is an example of long standing.

Control of the public domain would make possible the organization of livestock production on the basis of year-long feed and pasture. Properly done, this should eliminate much destructive early spring grazing on the winter and spring ranges and on the ranges of the National Forests. Delaying the opening of the grazing season has been one of the most difficult tasks of National Forest grazing administration. There is yet much chance for range improvement by later grazing season.

Proper Grazing Capacity or Rate of Stocking a Problem on All Ranges

Grazing capacity, or proper rate of stocking, is at once a most important and most complicated problem because of many factors involved:

Range usually is only part of the year-long feed supply. Improvement is improbable if grazing capacity is determined for a season beginning May 1 and then stock are turned on by April 1 because hay or early pasture runs out. The year-long feed supply of the production unit should be considered in determining grazing capacity for the range of such unit so that the *season* of grazing and *system* of grazing for which grazing capacity is determined can be followed.

The amount of range forage produced varies so much on account of species of vegetation, soil, and moisture supply that the individual pasture or small grazing unit is a problem in itself and in the end grazing capacity should be determined for the individual production unit (one ranch).

The rate of stocking for maximum use without injury varies with distribution of water and salt and with the handling of stock. These factors necessarily vary greatly and only rarely can they be made equal for two units.

Grazing conditions vary from season to season and the variation is not the same over large territory. Grazing capacity based upon production when growing conditions are above average means overgrazing in the end.

Figures on grazing capacity can be worked out for use as a guide over considerable *similar area*, but adjustments on the individual unit will be necessary, taking into account year-long and seasonal feed and range over a period of years, probable efficiency of range utilization, and plans for range improvement and maintenance.

Grazing Plan Should Provide for Natural Reproduction of Main Range Plants

On the 550 million acres, or any large part of it, range improvement,

for the present at least, must be accomplished through natural reproduction of the native or existing vegetation. *This means that species of grazing value must be given a chance to reproduce.* for western grazing this has been accomplished by: (1) protecting the range from grazing one or more years; and (2) deferring grazing until after the principal plants have matured seed or have completed vegetative reproduction.

The simplest application of these principles would be division of a pasture or range into two units upon which deferred grazing or protection is alternated. In practice on western ranges, however, a two-pasture plan rarely works. Three to five or six units are more often necessary, because the portion of the grazing period after seed maturity is short compared with the portion before. Further, protection or deferred grazing should be for at least two years in succession, in order to give the seedlings a chance to become established. And where the desirable species have been much weakened, seed of low vitality may be produced for a year or more after the protection is given, necessitating more than two years seed crop for appreciable improvement.

Every day of growth without grazing, especially early in the season, is an advantage. Therefore, each division of the pasture should stand its share of early grazing, other factors being equal.

The combinations of conditions are so many that no definite plan of grazing can be recommended with assurance that it will apply to an unknown combination of growing season, grazing season, character of forage, class of stock, topography, water and physical control.

A plan of grazing needs to be carefully worked out for each similar combination of conditions. This plan should then be adjusted to fit conditions on the individual unit.

EDUCATION THROUGH EXTENSION SERVICE

The agricultural extension service is beginning to recognize an opportunity for educational work in range improvement and range management. Better understanding and increased appreciation of range resources and their conservation should be brought about through such educational work, especially if undertaken by men who have sufficient understanding of the problems to adjust and apply what is known to the individual case. The individual case will rarely fit a standard recommendation. All agencies, state and federal, should cooperate in this project. Each agency should first get together the facts applicable to their regional conditions. Then, more enthusiasm than in the past would be a good thing.

FEDERAL AND STATE AGENCIES SHOULD COOPERATE IN DEVELOPING PROGRAM OF INVESTIGATIONS

Much information has been gained through the work of federal and state agencies in the past fifteen years. There is great need, however, for investigations to meet the problems enumerated, and others, for different areas throughout the 550 million acres. Federal and state agencies might well cooperate in deciding:

1. Division of the western ranges into *areas* where conditions are near enough alike that problems of improvement and management can be satisfactorily investigated at one experiment station.
2. The major problems which should be undertaken by the station serving each such area whether there is a station established or not.
3. The stations needed in addition to those already established.
4. The problems which are primarily federal, those primarily state.
5. Plans for cooperation and coordination to minimize duplication and encourage exchange of plans and results as fast as they are obtained.

4. PASTURES

C. THE PROBLEM OF SYSTEMS OF GRAZING[1]

WILL C. BARNES[2]

Lack of system in the handling of stock grazing the ranges is one of the most serious causes of range deterioration. This may be divided into two general causes:

1. *Too early grazing* in the spring when the ground is soft and the forage has not yet gained sufficient growth to withstand cropping.
2. *Lack of proper distribution*, the stock being allowed to graze as, when, and where, they please. Such grazing results in a concentration at waterholes, salting grounds, or in open meadows or park-like places, leaving portions of the ranges either absolutely untouched or only slightly used. Cattle are gregarious, and, like human beings, prone to follow the lines of least resistance. If left to themselves, they will naturally feed where feeding is easiest. Livestock of all kinds will graze uphill if they are encouraged to do so, but as long as there is any feed to be found in the bottoms they do not take kindly to climbing rough, broken mountain sides even though they find much better feed.

[1]Paper read as part of the symposium on "The Forage Problem" at the meeting of the Society held in Chicago, Ill., November 12, 1923.

[2]Assistant Forester in charge of Grazing, Forest Service, U. S. Department of Agriculture, Washington, D. C.

The first condition, that of too early grazing, is one that Forest Service investigators have solved fairly well, by regulating the time when the stock are to be placed on the ranges. In the early days of handling the National Forest ranges little attention was paid to this matter. The stockmen had always turned their cattle onto the public domain from their ranches very early in the spring, because as a rule by March first their hay and home pastures were exhausted. Thus, there had grown up an entering period for the National Forest ranges as early as the 1st of April, and seldom later than April 15th. A few years study proved that date to be entirely too early, for forage plants must be given a reasonable opportunity to gain some fair growth, if they are to maintain themselves against constant grazing. The decision to postpone the opening date for from twenty to thirty and in some instances, forty days, met with great opposition from the permittees interested. The majority of them offered the same plea which forest officers were making for the forest ranges, namely, that their own pastures were soft and the fresh green grass would be ruined if they retained their stock on them after the first of April. This of course was exactly the Forest Service argument, but naturally the stockmen were not as deeply concerned in the welfare of the government ranges as they were in their own pastures. The Forest Service persisted, however, and at the present time these entering dates are established late enough so that on the majority of national forest ranges the stock are not allowed to enter until the grasses and forage plants have reached a growth which will enable them to sustain grazing and not be injured thereby. The same situation holds good with sheep, excepting that as a general rule the sheep men are able to keep their stock on their own ranches or winter ranges considerably later than are the cattle men.

The matter of distribution over the ranges has been solved to a very large extent through placing salt at strategic points on the range, and especially at a distance from waterholes, watering places, or meadows. It has been learned that cattle will go into the roughest kind of areas and climb almost any ordinary mountain side in search of salt. By this means, a very satisfactory distribution of the cattle over the entire range has been secured, resulting in even, regular grazing without any unusual concentration at certain points. The ranges are grazed consecutively, placing salt on the lower ranges at the beginning of the season and, as the forage higher up advances in growth, moving the salt there, thus coaxing the cattle from one elevation to another as the season advances. A fair amount of rotation grazing has also been secured by this means, the cattle being tolled from one part of the range to another during the season

by moving salt ahead of them. By reversing the process the following year a systematic rotation of pastures grazed has resulted, thus bringing about a steady normal growth of forage plants during the entire season, no portion of the range being overgrazed at any time.

Sheep, since they are constantly under the care of a herder, are much easier handled and therefore the plans for rotation grazing now in use have worked out remarkably well. Each permittee is given a blue print of his range on which the various "camps" and dates of use are marked.

One of the most satisfactory methods of handling sheep is that called the "open" or "blanket" system of herding. Open herding means allowing the sheep to graze at will during the day, scattering out as widely as they please, within certain reasonable limits; never throwing them together in solid masses, if that can possibly be avoided. This does not mean, of course, that they are allowed to run absolutely at their own free will, for the herders are expected to keep a watchful eye on each herd. Instead, however, of rounding them up with dogs and massing them several times a day as was the former custom the herder quietly wanders around the outer limits of the area upon which the sheep are feeding, turning in any that show a desire to stray too far. In the evening, instead of driving them in one solid body to some established bed ground, the herder works his way around outside the lines, pointing them in towards a given center but not driving them, allowing them to bed down in small bunches, but within sight of each other, wherever night overtakes them. The herder's burros which have been with the herd all day are then unpacked and camp is made near the sheep. Dogs are strictly taboo except as company for the herder. Experience has shown that under such conditions twenty to thirty percent more sheep can be grazed on a given area, that the lambs weigh more at the close of the season, and that the range suffers much less from feeding, trailing and other forms of damage through use by sheep.

Singularly enough, the losses from predatory animals are actually decreased. The sheep men accepted this finding only after careful study and demonstration had proved it to be the fact, as they were firm in their belief that unless kept in reasonably close masses, especially during the night, there would be heavy loss from predatory animals. Experience and study have justified the belief that the fact that the sheep do not return to the same bed ground night after night rather puzzles the predatory animals and makes them more cautious about attacking the herd where it is spread out over a large area. The chief objection came from the herders, who rather enjoyed

going back every night to a permanent camping ground where they had more comforts than can usually be found in one-night stands. This objection was overcome by the owners, who agreed to pay an increase in wages to herders who handled their stock under this method, the owners realizing that the increased cost was fully repaid them by the improved condition of the stock and the range.

4. PASTURES

D. THE PROBLEM OF PASTURES IN SEMI-WASTE LANDS OF NEW ENGLAND[1]

S. B. HASKELL[2]

Decreased carrying power, increased invasion by weeds; gradual and in some cases rapid change from real pasture into open woodlot and later, after many years, into forest—this is the present tendency of the permanent pastures of New England, in as far as they are located on lands on which tillage operations are either impossible or too expensive to be practicable. The complex which has brought about these undesirable results is somewhat as follows:

A *glacial drift soil* derived from hard crystalline rocks, typically granites and gneisses, sometimes excessively drained, usually acid in reaction, locally filled with stones, boulders and rocks of all sizes and shapes.

A *topography* essentially rough and irregular.

A *climate* well suited to the growth of grasses and clovers, but even better suited to the growth of woody perennials and forest trees.

A *history* which in many cases includes two and a half centuries of use as pasture, typically without lime and without artificial fertilizer.

An *industrial situation* in the near-by cities which makes financially impossible the employment of labor to control weed growth by the only means yet developed since the land was settled, namely, hand mowing.

The two great problems are: first, the maintenance of fertility; second, control of weed growth. Since invasion of pastures by weeds is typically a result of diminishing fertility, it follows that these two problems are interrelated.

MAINTENANCE OF FERTILITY

These soils are typically acid. Natural flora indicates this, and chemical determination supports the diagnosis. Betterment in

[1]Summarized paper read as a part of the symposium on "The Forage Problem" at the meeting of the Society held in Chicago, Ill., November 12, 1923.
[2]Director Massachusetts Agricultural Experiment Station, Amherst, Mass.

pasture herbage from the application of lime may be expected. Agronomic history and experience indicate that some benefit from the use of phosphatic fertilizers may also be expected. Only where the soil materials are very coarse-grained, however, is it likely that any great change in vegetation would be caused by the use of fertilizer potash. The foregoing, however, represent theoretical considerations only. Pasture experimentation has not progressed sufficiently to confirm theory by actual fact. The work as done up to the present time at the Massachusetts Station fails to confirm these theoretical considerations.

CONTROL OF WEED GROWTH

Hairy cap moss, running cinquefoil, dewberry, and many other low-growing weeds, compete with grasses and clovers for possession of the soil. On normally well-drained soils, growth of these weeds may be controlled by the use of lime and fertilizers. Profit from such use is yet to be demonstrated, and is, of course, a function of price received for the products of the pasture as well as of cost of fertilizer. Apparently, the first step in preventing the growth of woody perennials is the producing of a good growth of grasses and clover in those pastures which are still in fair condition.

Where productivity of the soil is not maintained, or where there is insufficient stocking, woody perennials invade the pasture. Hardhack is ubiquitous. Alder is found in wet places. Gray birch is found everywhere. Ground juniper is a most serious pasture weed all over the New England territory. In many pastures, the harvest of blueberries and huckleberries is of greater value than is the product of the land as a pasture. Near the coast, bayberries present a rather difficult problem. Sweet fern is found in dominance on many of the drier soils. Ferns and brakes abound in moist situations. Most of these weeds, sooner or later, serve as cover for the early growth of forest trees, and in this way lead to ultimate reforestation.

Ignorance of the growth habits and requirements of most of these plants is shown by the fact that the pasture is considered as the unit rather than the types of growth found in the pasture. The causes which bring about dominance of one type of vegetation or another have never been fully explained. The significance of dominance, in relation to soil conditions, has not been established. Existing records of the life history of most of these weeds are superficial. No exhaustive study of methods of controlling growth has been made. This subject, in its entirety, promises to be a most fruitful field of agricultural research.

4. PASTURES

E. THE PROBLEMS OF PASTURES IN THE SEMI-WASTE LANDS OF THE SOUTHERN COASTAL PLAIN[1]

JOHN R. FAIN[2]

The semi-waste lands of the Southern Coastal Plain region are coincident, to a large extent, with the cut-over lands. The timber has been taken out fairly rapidly in the last few years, and a considerable portion of the cut-over lands remains unfenced and undeveloped.

For those who are unfamiliar with the Coastal Plain conditions, it may be well to give a brief description of the section. In topography, it is gently undulating. The soils are usually sands or sandy loams. In the lower areas, there is often a very thick growth of shrubs and trees, a large number of which are thick-leaved evergreens that give practically no browse. On the higher areas, there is a scant growth of young pines, left when the land was cleared, or seedlings that have come up since the timber was taken off. Grass and a variety of other plants are scattered through this growth. The predominating grass, at least in many sections, is wire grass (*Aristida stricta*).

THE UTILIZATION OF NATIVE PLANTS

The first problem that presents itself is the utilization of the native growth. In some sections of the Coastal Plain region, this growth is rather abundant, but when the whole year is taken into consideration, it furnishes only a limited amount of feed. One reason for this is that practically all the native grasses of this section make rather a large growth and soon become harsh or wiry. At this stage, the animal has a hard time to secure nourishment enough to make a livelihood; or to put it in the vernacular of the cattle men of some sections of the Coastal Plain region, "There are five months of feed and seven months of starvation."

It is customary to burn the open range each winter, the idea being that the grass will come earlier and the animals will thrive better than if they try to glean the new growth from among the dead stems of the year before. By this means, for a period of from sixty to ninety days, very palatable, and apparently fairly nutritious, grazing is provided.

[1]Paper read as a part of the symposium on "The Forage Problem" at the meeting of the Society held in Chicago, Ill., November 12, 1923.

[2]Professor of Agronomy, Georgia State College of Agriculture, Athens, Ga.

A problem growing out of the utilization of native vegetation is the type of animal best able to convert any food material found in the open range into a marketable product. Naturally, a hardy type of animal is needed. The native animal, the product of this condition, one that can stand an adverse environment, is not the type which is desired to any great extent by the markets. Under certain conditions, a half-blood animal may be able to glean a livelihood. However, some of the cattle men who have studied this problem contend that a quarter-blood animal is about all that can be expected to maintain itself under such conditions. This type is some improvement over the native animal; and while it is not to be looked on as a permanent proposition, it does give some income from a source that otherwise would produce none.

On both the small farms, that is, farms of a few hundred acres, and the larger holdings, pasturage will probably be combined, to a certain extent, with forest production. Many problems connected with this combination remain unsolved; but it offers a possibility of using a good deal of land, at least for the next timber generation, that could not be utilized in any other way.

The eradication of the native growth is one of the first steps toward better pastures. Here again, the use of fire, combined with heavy grazing, will help materially. While indiscriminate burning is to be condemned, the judicious use of fire in ridding the ground of an excess of coarse material is probably necessary. If the land is stocked sufficiently to keep the grass short for a greater part of the year, a large number of the native species disappear. Plowing will eliminate the native grasses, when it is practicable to plow.

ADAPTATION OF BETTER PLANTS

Finding the Plants

The temperate-zone plants, which have been developed in Europe and are of great value in the northern part of the United States, do not find congenial soil or climate in the Coastal Plain. In fact, it is only the exceptional plant that will stand the heat, and only under favorable conditions. On the other hand, a great majority of the tropical plants are not adapted to this region, because of the occasional low temperature in the winter months. It must be borne in mind that the plants must withstand not only the average conditions of heat and cold but also the extremes. An interesting fact, in this connection, is that Japan clover (*Lespedeza striata*) was first found in the United States not very far north of the Coastal Plain. This plant has spread northward and covered a considerable territory, but has not invaded the Coastal Plain to the southeast to any appreciable

extent, although the natural drainage of the section where it was first found runs through this region. The extremes of many years, it would seem, are unfavorable to the seeding of the Japan clover.

One of the difficulties with the plants adapted to this section is to find a suitable combination. Plants which supplement each other and would give the maximum length of grazing permitted are often hard to combine successfully into a pasture. Most of the plants available make their principal growth in mid-summer. An extension of the grazing period is needed for spring and fall.

Fungous Diseases

Another problem of a moist, warm section is that of fungous diseases. Not a great deal is known about the fungous diseases of pasture plants. It is probably safe to assume, however, that disease-resistance is just as necessary in pasture plants as in other cultivated plants. This is a particular problem in connection with legumes; yet legumes, it would seem, are vitally necessary in this section.

Climatic Conditions

With an annual rainfall of forty inches or above, no serious problem should be found in connection with moisture. It is not the lack of sufficient yearly rainfall, but the distribution of the precipitation that produces the problems. The tendency is for more-or-less alternate periods. The winters have from a moderate to a low rainfall, which is not very favorable for winter-growing plants. This period is followed by a rather heavy spring rainfall, which, in turn, is succeeded, in the late spring and early summer, by droughty conditions. In mid- and late-summer, the rainfall is usually excessive, while the falls are generally very dry.

In considering the moisture problem, the rapid evaporation must be taken into account. This is caused by a combination of factors, such as heat, rapid capillary movement of the moisture in the upper soil layers, and a fairly regular breeze at certain times of the day.

The temperature of the lower Coastal Plain rarely falls to a point where growth is checked. A few years ago, the writer was in Colquitt County in southern Georgia on a February day. The county agent made the statement that it was the coldest morning of the five years that he had been in the county. The thermometer had registered twenty-seven degrees.

Reference has been made to the fact that tropical plants do not withstand the winter temperatures, and a word of explanation is probably in order. As indicated by the Colquitt County agent, plants do not often have to stand a low temperature, and a very

slight cold-hardiness would seem to meet the situation. The difficulty arises, however, from the periods of growth, followed at times by sudden checks on account of drops in temperature. A drop, for instance, from 70° to 30° might possibly be just as disastrous to some plants as a drop from 30° above to 10° below zero would be to others. Some years ago in Athens, Georgia, a number of barleys grown in the variety tests were completely destroyed by low temperature. But the same barleys, the same year, stood a much lower temperature at the Arlington farm near Washington. The only explanation of this phenomenon that can be offered is that the barleys at Athens had experienced a period of moist, warm weather, and were making a very vigorous growth, while the barleys at Arlington had not started the vegetative growth of the spring.

On the other hand, plants must be able to stand fairly high temperatures, if they are to succeed in the Coastal Plain. It is not a matter of an excessively high temperature for a short time, but a fairly high temperature for a considerable period. It is also a high temperature from early morning until late in the evening. It is the continuousness of the heat that makes it hard to endure. Periods of drought also intensify the condition that the plants have to withstand. The soil texture is such that it heats up readily and at times the soil becomes exceedingly hot.

Soil Conditions

Most of the pasture plants require a compact soil. Not a great many soils of this type are found in the Coastal Plain. Most of them are of a sandy nature with the loose, friable condition which is characteristic of soils of this texture. It has been found more desirable with the plants now in use, under a good many conditions, to make the seedings for pastures on unplowed land, if the natural growth will allow this to be done, rather than to plow it. Such plants as carpet grass appear only after the land has been compacted, as along wagon roads where logs have been hauled out.

The soils of this region are extremely varied in type, and but little is known as to the kind of plants which are adapted to many of them. The variations in some of the soils are difficult to detect. The difference in value of one soil type is indicated by the presence or absence of a single plant. Wherever this particular plant is found, the land is not worth considering.

Another problem difficult to meet is the excess of moisture of the swamps and marshes and the extreme dryness of some of the higher areas, with all gradations of moisture-content between these extremes. The topography of this section is such that these extremes are often

found side by side, which frequently makes it exceedingly hard to establish pastures on areas that, for other farm considerations, are the best ones on which to put them. As a general proposition, the moist lands offer the greatest promise for pasture development. The utilization of this type of soil has been partly solved. On the other hand, the utilization of the higher, dryer lands for pasture development is a very difficult problem.

The problem of clearing and draining the low land cheaply enough to make the development of pastures practicable is often difficult to solve. In clearing for pastures, the judicious use of fire seems to be the most practical method of solving the problem, at least in part. The use of fire, in connection with heavy grazing, will help materially to put these lands in proper condition. Some of these low lands have been badly leached and have very low producing power. Just how to handle lands of this sort, which have the essential moisture, but not the other essentials, is still unsolved. It is true that most of the lands of this section are low in the essential elements needed for crop production, but it is also true that these soils have a comparatively high availability of these elements.

How to treat these lands to maintain pasturage for a long period is another unsolved problem. To what extent commercial fertilizers can be used in a profitable manner has not yet been ascertained. Fertilizers can probably be used to good advantage in establishing pastures. How often they should be used thereafter, and in what form, remain to be worked out.

Seed Supply

Another problem that comes up continually with the better plants, when found, is a source of seed. Some of the plants available for pasturage, for at least some sections of the Coastal Plain territory, have to be propagated vegetatively, making pasture building slow and expensive. Then, too, it is only recently that very much attention has been given to harvesting the seed that are available. Not a great deal is known yet in regard to the best method of saving these seed. Such plants as Dallis grass (*Paspalum dilatatum*) are affected, in the region under consideration, with a fungous disease that makes it difficult to harvest a seed crop of high germination. So far, most of the Dallis grass seed used commercially has come from Australia. A source of seed so distant as this increases the difficulties of the problem. With some of the plants, a source of seed has not been established; or, if established, a method of handling the seed so that the results will be uniformly successful, has not been sufficiently well established to make them a commercial possibility, as, for example, with the Bahia grass (*Paspalum notatum*).

GENERAL CONSIDERATIONS

Periodic Grazing

The uneven distribution of the rainfall, already noted, brings about conditions in growth that make it difficult to stock the pastures in such a way as to keep the grass always palatable. Practically all the pasture plants that can be utilized in this region to advantage are of such a nature that excessive growth makes them less acceptable to the animals. The pasture properly stocked in the early spring will often be over-stocked in the late spring and early summer, decidedly under-stocked in mid-summer, and again badly over-stocked in the fall. The only method devised so far is to cut the pasture for hay in the late summer, which makes the problem of reserve pastures during droughts an acute one. This problem will probably have to be solved by utilizing for reserve pastures areas other than the permanent pastures.

Parasites

Another problem, which has been given rather wide publicity, is the infestation of pastures in this section with animal parasites. Some time ago, the Veterinary Division of the Georgia State College of Agriculture was requested to give this matter consideration. A trip made by the veterinarian through the Coastal Plain region of the state and an examination of the animals on the pastures, particularly on pastures that have been used for many years, did not reveal a more serious condition than would be found in almost any other section. However, the main problem is the control of pastures that have become infested, as all pastures where livestock are handled continuously are liable to some kind of infestation. It has been suggested that, in the absence of low temperatures, parasites will multiply rapidly. It is true that this section has very little benefit from low temperatures, but the effect on parasites of heat and the dryness of the upper soil crust have been practically overlooked.

Recently, a questionnaire was sent to the practicing veterinarians in the Coastal Plain region, asking for information in regard to the effect of the pastures infested with parasites. Ninety percent of those who replied believe that no more serious conditions exist in the Coastal Plain than in the well established livestock sections. Ten percent believe that the conditions are worse. The following answer of one of the veterinarians is of interest. He said, "I do not consider the parasitic infestation of livestock any worse, if as bad, as in the Middle West, where I was raised."

Developing a System

Each section of this country, where livestock is handled successfully,

has worked out a system of managing pastures and livestock that covers all the problems connected with the local environment. Such a system has yet to be developed for the Coastal Plain region. There is, it is true, a system after-a-fashion, in handling the animals on the native growth; but looking forward to the development of a livestock industry that will produce a better class of animals, in connection with permanent pastures of real value, a system must yet be evolved. Such a system will come slowly, as experience is accumulated and as a more intensive study of the problems is made.

CONCLUSION

The title of this paper indicates that the problems only are to be presented. Therefore, no attempt has been made to set forth any of the successes in pasture building in the Southern Coastal Plain. It may be well to say in conclusion, however, that some of the pastures developed in this section are notable for their carrying capacity. It is believed that solutions of some of the problems are under way and that before a great while permanent pastures will be a large factor in the successful agriculture of this region.

5. THE BETTER UTILIZATION OF STRAWS[1]

C. E. Leighty[2]

Straw is the dried stalks or stems and other parts of various crops from which the seed has been removed in the ripe or nearly ripe stage. Straw refers especially to the remnants after threshing of the small grains, wheat, oats, barley, rye and rice, but is also properly applied to threshed buckwheat, peas, beans, flax and other crops handled in the same way.

The ripening processes of the plant consist largely in the transfer of soluble materials from the leaves and stem to the seed. So it is found that seeds, in general, are rich in protein, fat, and carbohydrates, while the remaining portions—the straw—are comparatively poor in protein and fat, although retaining considerable amounts of carbohydrates. The larger part of the carbohydrates, however, usually is not digestible, being tough and woody in character.

The fertilizing constituents of straw are not notably high. The content of potash is usually highest of that of the three constituents, nitrogen, phosphoric acid and potash. Thus, a ton of wheat straw

[1]Paper read as a part of the symposium on "The Forage Problem" at the meeting of the Society held at Chicago, Ill., November 12, 1923.

[2]Agronomist in Charge of Eastern Wheat Investigations, Office of Cereal Investigations, Bureau of Plant Industry, Washington, D. C.

contains on the average about 10 pounds of nitrogen, 2.6 pounds of phosphoric acid, and 14.8 pounds of potash. Oat and barley straws contain slightly more nitrogen and phosphoric acid and about twice as much potash as wheat straw. Rye straw contains slightly less nitrogen than wheat straw, but slightly more phosphoric acid and potash. The straws from cowpeas, soybeans, and, in general, from other leguminous crops, are comparatively high in nitrogen but not materially higher than wheat straw in phosphoric acid and potash. Soybean straw, for instance, contains, in each ton, about 18 pounds of nitrogen, 2.4 pounds of phosphoric acid and 17.8 pounds of potash.

It is seen, therefore, that straw is a substance of large bulk but of low manurial and nutritional values. The problem is to utilize these materials in such a way as to conserve their valuable constituents at the minimum expense of handling.

The following methods of making use of straw suggest themselves: first, using it directly as feed for livestock; second, using it for manure by adding it to the land either before or after decomposition; third, burning; fourth, using it in manufacturing; and fifth, making from it, by different processes, a feed of higher nutritive value.

STRAW AS FEED FOR LIVESTOCK

Straws and stovers are the least nutritious of all substances commonly used as feed for livestock. Such animals as can be maintained on straw are hardly more than able to keep alive for any considerable period on this material alone. Sometimes, when considerable grain is mixed with straw, it makes a fairly good feed, but this is on account of its grain content. Utilized in connection with other feeds, however, straw has a valuable feeding role and must be considered as of

TABLE 1.—*Straws and stovers. Total production, amount eaten by livestock, and number of cattle each item would support for one year.*

(000 omitted, except in annual ration)

Forage	Acreage	Total yield	Amount eaten	Theoretical annual ration	Number of cattle each item would support for 1 year
	Acres	Tons	Tons	Tons	Number
Corn	87,772	75,000	25,000	11	2,273
Oat	40,361	34,000	10,000	11	900
Wheat	73,099	43,000	4,300	15	290
Sorghum	3,857	4,946	2,473	11	225
Barley	8,013	3,000	750	15	50
Cotton (seed hulls)	—	1,143	600	12	50
Rye	7,679	5,000	250	15	17
Rice	911	911	90	11	8
Flax	1,261	315	65	11	6
Totals		167,315	43,528		3,819

considerable importance. In Table 1, the yields of the particular crops yielding straw are shown, together with an estimate of the amount of each straw actually eaten, and the number of cattle that each would theoretically support for one year.

Wheat and rye straws are usually considered as least valuable for feeding purposes. Oat and barley straws are more valuable, as was indicated in statements above concerning their composition. They are also softer and more easily masticated. Of the common domestic animals, sheep are best adapted to utilize straw. Corn stover is more digestible than the straw of the small grains and seems to be more palatable but unless it is shredded, waste is very large. The labor of shredding or cutting may more than offset its greater digestibility. The legume straws, although richer in protein and lower in fiber, and, therefore, more highly digestible, are usually coarse in texture and often have a rather unpleasant taste that tends to neutralize their other attractive qualities.

It may be said, therefore, that straw in general could be more widely used as a food for livestock where and when it is profitable to use it in connection with concentrated feeds that form the nutritive portion of the ration.

The palatability of straw is increased by cutting or grinding it and mixing, the day before feeding, with cut roots, one part of straw to 9 or 10 parts, by weight, of roots being advised. In Australia straw chopped in short lengths (called chaff) and treated with live steam is an important feed, especially in dry seasons.

Feeding Without Threshing

According to estimates by the United States Department of Agriculture, published in the Monthly Crop Report for February, 1917, the portions of the four principal small grain crops that were allowed to mature and were then cut but not threshed, that is, were used as feed in the straw, are as follows: wheat, 0.7 percent; oats, 7.8 percent; barley, 1.3 percent; rye, 1.8 percent. It appears that oats are especially desirable for this purpose, inasmuch as more oats are used in this way than all other crops combined. This practice is especially prevalent in the Southern States, more than fifty percent of the oat crop being used in this way in most of these States.

This method of handling the oat crop has certain evident advantages: first, expenses are reduced by not threshing the grain; second, storage need not be provided for threshed grain, although space is needed for storing the grain in the sheaf, which would not be needed if the threshed straw were stacked in the open; third,

oats in the sheaf are more easily fed than grain and straw separately; and fourth, better utilization of the straw is obtained. It is believed that much of the oat crop could be utilized in this way, that is, by cutting the grain when ripe and then storing it in mows to be used as feed in the unthreshed condition.

The value of oat straw for feeding purposes depends largely upon conditions under which it was grown, as has been pointed out by Collins (2).[3] The amount of albuminoids in the straw depends chiefly on the amount of nitrogen supplied to the root and the amount of nitrogen demanded by the grain. In general, the more nitrogen in the soil, the more albuminoids there will be in the straw, although much depends on the quantity of grain produced. Good farming practices, in which the soil is enriched by applications of manures, increase the albuminoid content of the straw, within certain limits, of course. The lowest figure obtained by Collins for albuminoids is 1.1 percent, and the highest 8 percent. Samples of oat straw from different districts in England and Scotland varied in average albuminoid content from 2.7 percent to 4.4 percent.

Sugar content in straw also may vary widely. This is not dependent so much on soil condition but is largely dependent upon weather conditions at time of harvest, and also upon storage conditions. Fine weather during harvest appears to be essential for obtaining high percentages of sugar. Sugar gradually disappears from the straw after harvest, the loss being proportional to the moisture content. Under average conditions, high sugar content is not common, but under careful management, six-month old straw has been found very rich in sugar. The highest total sugar content reported by Collins is 9.7 percent, and the lowest 0.3 percent. The feeding value of oat straw, therefore, may be quite high under certain conditions and comparatively low under other conditions.

ADDING TO LAND

The manurial value of straw is well known and need not be especially emphasized. As indicated by analyses and by field experiments, straw and manure made from straw are low in phosphorous and for best results should always be reinforced or supplemented with this element. Used in this connection, there is no better fertilizing material for general use than manure. While farmers generally recognize this fact, nevertheless, it should be continually emphasized, as there is doubtless great waste of valuable fertilizing materials on many of the farms of the country.

[3]Reference by number is to "Literature Cited," p. 223.

Adding Straw to the Soil

Experiments conducted by Scott (12) in Kansas showed that heavy applications (four tons per acre) of straw to wheat growing in the field retarded growth the following spring, delayed the ripening of the grain and reduced the yield, except on soils having a high nitrate content when the straw was applied. Four tons of straw per acre worked into the surface six inches of uncropped soil resulted in a lower nitrate content the following spring, but during the summer the accumulation of nitrates was equal to that in the untreated plats. Two tons of straw handled similarly did not lower the nitrate content of the soil the following spring.

From the results obtained by Murray (10), working in Washington, it appears that straw added to the soil stimulates the reproduction of bacteria and that they use the straw as a source of carbon and the soil nitrates (or in some cases ammonium sulfate) as a source of nitrogen. The nitrates are thereby transformed to organic nitrogenous material, and are lost for the time as available plant food, but are not lost permanently to the soil. The larger the application of straw, the greater the development of bacteria and the more intense the action.

Straw as Mulch

The application of straw as a mulch to winter wheat has been practiced in some places. Under severe conditions, as reported from the South Dakota Station (3), a light application, not exceeding two tons of straw per acre, has given good results. Other reports also indicate that a straw mulch oftentimes will protect the wheat from very severe winter conditions, but that it must not be added in too large quantities, as more harm than good will result on account of smothering, and possibly by reduction in nitrates.

BURNING

In 1914, estimates made by the United States Department of Agriculture and published in the Office of the Secretary Report No. 112, indicated that about 15 percent of the straw of the small grains, or 17,613,000 tons in all, and 3.7 percent, or 9,000,000 tons, of the corn stover were burned. Straw is burned chiefly in sections of the country where the livestock population is small and where it does not seem to be especially advantageous to add it to the land. Under such conditions, the practice of burning straw may be the best method to follow; although, in general, it appears to be a wasteful procedure.

Burning Straw and Stubble and Plowing it Under

On the dry lands of the western United States where fallowing is

practiced, difficulty is frequently experienced in cultivating fallow after a heavy growth of stubble and straw is plowed under. In eastern Washington and eastern Oregon, wheat is customarily harvested with the combined harvester, which leaves a large part of the crop growth on the land in the form of stubble. Most of the straw which goes through the machine is likewise left in piles or windrows in the field. In this section of the country, therefore, the farmers quite generally burn the straw and stubble before plowing. This may be done either late in the fall or early in the spring.

At the Nephi, Utah, substation, an experiment (13) has been in progress since 1916 to determine the comparative effect on the yield of wheat of burning the stubble and straw on the land and of plowing them under. Four methods of handling the stubble and straw were compared with ordinary fall-plowed fallow. The methods compared were (1) all straw plowed under, (2) all straw burned on plat, (3) grain headed high and stubble plowed under, and, (4) grain headed high and stubble burned. Slightly the highest average yields in the 6-year period, 1916–1921, were produced where all of the straw was burned, and slightly the lowest where all the straw was plowed under. The difference between the highest and the lowest average yield, however, was only one bushel per acre. Nephi is located in the dry-farming area, the average annual precipitation being 13.33 inches. Although the data at hand are not sufficient for safe conclusions, even for the particular locality concerned, it is apparent that the yield has not been reduced by burning the straw and stubble, neither has it been increased by plowing them under.

USING STRAW IN MANUFACTURING

Over 150,000 tons of wheat, rye and oat straw were used for making wrapping paper and strawboard in the United States in 1908. Apparently it is very little used for the manufacture of bleached paper pulp for news and printing papers. Rye straw was used considerably for this latter purpose some fifty years ago. There may be some increase in the use of straw for paper making in the future, but it is improbable that there will be any large increase in the near future. Rye straw is used for certain special purposes, such as making horse collars, packing furniture, crockery, and nursery stock, and in foreign countries for thatching cottages and in a variety of other ways. It does not appear that any large increase is in prospect or possible in these directions.

Production of Gas by the Destructive Distillation of Straw

During recent years, numerous experiments have been conducted in the United States and Canada on the production of gas by the

destructive distillation of straw. In order to obtain additional information on this subject, straw-gas equipment was set up at the Arlington Experiment Farm of the United States Department of Agriculture. The results of the experiments conducted on the production of gas from straw have recently been published (11).

These experiments have shown that straw gas can be produced for heat, light and power, but that the production of such gas *on farms* is not practicable at the present time. In arriving at this conclusion, the cost of production including cost of equipment, raw material, labor and depreciation have been taken into account. It is possible, however, that the manufacture of gas from straw under certain conditions might be profitable and feasible. The possibility of developing community gas plants for towns and villages in sections where there is much waste straw should be carefully considered.

In this process dry straw or similar material is heated in a closed container in much the same manner and for similar purposes as coal is heated in making coal gas. The products of this distillation are gas, tar, ammonia, and carbon char or residue. A satisfactory gas has been made from many waste vegetable products, including wheat, oat, flax, barley, rye, rice, and other straws, corn stalks, corn cobs, sawdust, and other cellulose material. As heat is applied to the retort gas begins to come off when a temperature of 200° C. has been reached, with a maximum production at a temperature of about 500° C. After being cleaned by passing through water and coke or charcoal, this gas is stored in the ordinary water-seal gasometer.

A ton of sun-dried wheat straw will produce approximately 10,000 cubic feet of purified gas, 625 pounds of carbon residue, 10 gallons of tar and a large quantity of ammoniacal liquors. The gas has a heating value of 400 British thermal units per cubic foot. The combustible constituents are carbon monoxide, hydrogen, and methane. It can be used in gas stoves, heaters, and for lighting purposes in gas mantle lamps. It is satisfactory as a source of power for operating stationary internal-combustion engines. It has also been used for running automobiles, the straw gas being carried in a flexible bag containing about 300 cubic feet, a quantity sufficient to run the car 15 miles. It will not be practical for this purpose until the gas has been compressed or condensed sufficiently to permit its being carried in a satisfactory manner. The gas also can be used at once after it is made for generating additional gas from straw, about 3,000 cubic feet being required to carbonize one ton of straw, which produces approximately 10,000 cubic feet of purified gas. The gas

from a ton of straw is equivalent in heating value to approximately 37 gallons of gasoline.

As stated above, in some sections of the country large quantities of straw and corn stover are burned. The quantity disposed of in this way was estimated in 1914 as 26,613,000 tons. This amount of straw and stover would produce more than 175,000,000,000 cubic feet of gas if one-third of the crop were used to carbonize the remainder (assuming the quantity of gas produced from the different straws and corn stover to be the same as that from wheat straw). This quantity of gas would be equivalent in heating value to about 650,000,000 gallons of gasoline. In addition there would remain large quantities of more or less valuable by-products.

PROCESSING STRAW

Straw is made much more digestible by chemical treatments, known as "processing." The basic principle of the methods which have been successfully employed up to the present time is hydrolysis of the chemical compounds of the straw, usually with soda or sodium hydroxid. In Germany, much attention was given during the war to methods of improving the feeding value of straw and other materials of relatively low nutritive value. According to one report, 10,000 tons of straw were processed in different ways in one month in 1918. This was used in place of imported feeds on which the livestock industry previously had been largely dependent.

A number of publications, only a few of which can be mentioned here, have been issued within the last few years dealing with methods of processing straw and other materials, and with methods and results of feeding the product. Hiltner (5), in connection with a discussion with special reference to war conditions of the forage products, cultivated and wild, available in Germany, discusses the methods of treating straw to make it a desirable feed. Magnus (9) discusses the development of the practice of processing straw and the action of caustic soda on straw, and describes the methods used in processing and in analyzing the product.

In one of the oldest methods, straw is cooked in an open kettle for six hours in a caustic soda solution by means of steam at not more than .5 atmosphere pressure. One part of caustic soda is used for each 10 parts of straw. After cooking it is necessary to wash out the alkali, by which process about 30 percent of the organic substance is lost. The starch value of the remaining product, however, is reported to be more than three times that of untreated straw. The process is reasonably easy of application, but rather expensive on account of the large use of lye.

Various other methods have been tried, in which straw is cooked in soda, caustic soda, or caustic lime solutions without pressure, or under steam pressure up to 5–6 atmospheres. When pressure is applied the quantity of soda used may be reduced to as low as two percent. When so reduced, it is not necessary to wash the product, but lower digestibility results. Other processes, making use of acids and chlorine gas, were tried during the war, but apparently have not given good results in rendering straw more digestible.

One of the most recent and apparently the best method is the patented Beckmann process (1), in which cooking is not required. In this process, finely cut straw is covered with eight times its weight of 1½ percent caustic soda (NaOH) solution. After standing four hours, the liquid is poured off and the processed straw washed to remove the remaining alkali. The recovered liquid contains about half the original NaOH and can be used for the next batch of straw by adding the proper quantity of fresh NaOH solution. New solution must be used for the fourth batch, however, because of accumulated lignin material in the solution.

The action of the materials used in processing, whereby the straw is made more digestible, is developed in detail by Magnus. It consists briefly in removing or loosening the lignin and other substances that protect the cellulose of the cells. Apparently, complete removal of the lignin is not necessary, the essential action being the softening of the crude fiber and breaking down the strong connection between lignin and cellulose. That treatment is best which, in the shortest time and with the smallest quantity of chemical, removes or loosens as much of the lignin as possible, with minimum loss of organic material. From this standpoint the cold process is preferred, since it removes more lignin and causes less loss of the digestible organic substances than the process involving pressure and high temperatures. Boiling for three to five hours, without pressure, in 8–10 percent solutions of soda (sodium carbonate) or calcium oxid gave nearly as good results, however, as the Beckmann cold process with caustic soda. Methods in which these materials are used have the advantage that both soda and quick lime are much more easily and safely shipped and handled than caustic soda.

Results of a number of investigations on methods of feeding, digestibility, and chemical analysis of processed straw have been published in the last few years, especially by German authors. This feed, like the straw from which it is made, is low in protein and fat. That made with strong caustic soda lye solution, which therefore must be washed, and that processed at high temperatures under

pressure are especially low in these substances, as the small quantities which are originally present are largely washed away. The washing also tends to render the feed tasteless and it is not readily eaten by stock. Honcamp (6) concludes that hydrolysis under pressure results in greater loss of organic matter than cooking in open vessels. When prepared by some of the methods the taste and smell are retained and the feed is more palatable.

Because of its low protein content, this feed is best used for oxen and work horses, but sometimes is fed to other animals. Mixing with molasses and ground lupine seeds (with the bitter principle extracted) gives a better balanced and more palatable feed. Substantial increases in digestibility of cereal straws result from treatment with sodium hydroxid, but only slight increases occur in straw from seed beets, rape and peas. Processed straw is fed in wet or moist conditions, containing usually 70 to 80 percent of water. It should be fed within 10–14 days after being treated, as it does not keep well.

Kling (7) has reported the chemical composition of straw processed by the Colsmann method, according to analyses by several investigators, as follows:

TABLE 2.—*Average composition of straw processed by the Colsmann method, as determined by Reisch, Köslin, and M. Schmöger.*

	Reisch		Köslin	M. Schmöger
	I	II		
Water	69.2	80.7	75.0	Dry substance
Crude protein	1.7	1.1	0.3	2.1
Crude fat	0.2	0.1	0.3	1.2
N-free extract	2.6	2.3	7.6	24.6
Crude fiber	24.8	14.5	16.0	68.0
Ash	1.5	1.3	0.8	4.1

Fingerling and Schmidt (4) have determined the digestibility of rye straw treated by the Beckmann process, described above, for different periods. The straw was supplemented by linseed meal, various salts, and in some cases molasses. The following are the averages of the digestion coefficients for each period of treatment:

TABLE 3.—*Average digestion coefficients (ruminants) for rye straw hydrolyzed with sodium hydroxid.*

Constituent	No treatment	Duration of hydrolysis: 1.5 hours	3 hours	6 hours	12 hours	3 days
	Percent	Percent	Percent	Percent	Percent	Percent
Organic matter	45.68	59.33	68.05	70.28	71.22	73.10
Crude fiber	58.02	69.21	77.50	79.78	80.94	72.25
N-free extract	40.15	48.10	57.58	57.28	60.30	78.52

The composition of the different samples of straw also is reported.

Several different forms of apparatus have been devised for manufacturing this processed straw. Many of these devices were installed in Germany during the war. One device, costing 9,000 marks in 1917, had a 24-hour capacity of about 4,400 pounds of straw. The cost of manufacture of processed straw was about 21 cents (at normal exchange rates) per hundred pounds of finished product, not counting the original cost of straw. The cost as reported for other methods appears to be considerably less, but it is not clear just what is included in the cost.

Another matter that seems worthy of note in this connection is the report by Lehman (8) that processed straw, to which ammonia was added, was inoculated with fungi and the protein content increased from 4.35 percent to 11.02 percent.

These methods for hydrolysing straw appear to be promising. That they are practicable under certain conditions was demonstrated in Germany during the war. The whole matter should be investigated in this country, in order to determine the usefulness and practicability of the methods under our conditions. Large quantities of straw are wasted in some parts of the country. If the feeding value of this straw can be increased two or three times, as seems possible by these treatments, it may be profitable under certain conditions to install necessary apparatus and, through the manufacture of processed straw, to develop the livestock industry in regions where the straw is available.

LITERATURE CITED

1. Beckmann, E. The supply of carbohydrates in war: Reform of the process of rendering straw soluble. Sitzber. Preuss. Akad. Wiss. 1919: 275–285. (Abs. in Chem. Abs. 13:2567. 1919.)
2. Collins, S. H. The feeding value of oat straw. *In* Jour. Min. Agr. (British), 29:993–997. 1923.
3. Evans, Arthur T., and Janssen, George. Winter wheat in South Dakota. S. D. Agr. Exp. Sta. Bul. 200:487–516. 1922.
4. Fingerling, G., and Schmidt, K. Die Strohaufschliessung nach dem Beckmannschen Verfahren. I. Einfluss des Aufschliessungszeit auf der Nährwertserschliessung. Landw. Vers. Sta. 94:115–152. 1919.
5. Hiltner, Lorenz. Vermehrte Futtergewinnung aus der Leimschen Pflanzenwelt. II Teil. 128–137. Eugen Ulmer: Stuttgart, 1918.
6. Honcamp, F. Über Strohaufschliessung. Landw. Vers. Stat. 95:68–89. 1919.
7. Kling, Max. Die Kriegsfuttermittel. Eugen Ulmer: Stuttgart, 1918.
8. Lehman, Franz. Die Aufschliessung von Stroh. *In* Deut. Landw. Presse. 42:295–296. 1915.
9. Magnus, Hans. Theorie und Praxis der Strohaufschliessung. Paul Parey: Berlin. 1919.

10. MURRAY, T. J. The effect of straw on the biological soil processes. Soil Sci. 12:233–259. 1921.
11. ROETHE, HARRY E. Experimental production of straw gas. U. S. Dept. Agr. Bul. 1203. 1923.
12. SCOTT, HERSCHEL. The influence of wheat straw on the accumulation of nitrates in the soil. *In* Jour. Amer. Soc. Agron. 13:233–258. 1921.
13. STEPHENS, DAVID E., MCCALL, MAX A., and BRACKEN, A. F. Experiments in wheat production on the dry lands of the western United States. U. S. Dept. Agr. Bul. 1173. 1923.

6. THE POSSIBILITIES IN NEW FORAGE PLANTS[1]

C. V. PIPER[2]

It is a trite and obvious remark to say that new forage plants, novel either as to introduction or to utilization, have in the relatively recent past contributed greatly both to the potential and to the actual forage production of the nation. It is necessary to recall but a few important examples.

PAST ACHIEVEMENTS

Alfalfa was introduced into California in 1851, and until about 1870 spread only gradually. Since 1885, it has been the premier forage plant of the whole region west of the 95th meridian.

Sorghum was first widely distributed by the Patent Office in 1857. It became a crop of major importance with the development of the relatively dry regions from Kansas to Texas beginning about 1890.

Japanese lespedeza was first found in the United States in 1846. During the Civil War it became widespread, and has become more and more important since that time.

Soybeans were introduced as early as 1829, but received little attention until a second introduction in 1854. The crop became of some importance beginning about 1885, but it is only in the past few years that it has gained large favor, as the rapidly increasing acreage shows.

Sudan grass, introduced in 1909, gained almost instant favor, and its importance has steadily increased.

Velvet beans, brought to Florida prior to 1875, were not used as forage until about 1890. The development of earlier varieties brought about a great increase in the use of this crop, beginning about 1917.

Sweet clover, early introduced, known mainly as a wayside weed

[1]Abstract of address at opening of symposium program, Chicago, Ill., November 12, 1923.

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and honey plant, but neglected as forage, suddenly gained favor about 1912, and since then its increased utilization has been noteworthy.

Sunflowers were practically not used at all until the Montana Experiment Station in 1919 published their findings that sunflowers make good silage. Wherever sunflowers will make decidedly more tonnage than corn they bid fair to replace that crop for silage. Schoth's discovery that a little salt added makes the silage much more palatable is important.

Confining, for the moment, the discussion to the above mentioned crops, there is more to be said.

More intensive studies of alfalfa led to the detection of better varieties, better at least for certain areas. Such include Grimm alfalfa and Peruvian alfalfa.

With the sorghums the results are far more striking, as witness the numerous varieties now grown, many of them of recent introduction, such as milo, kafir, feterita, honey sorgo, etc.

The study of soybeans has revealed the existence of a large wealth of varieties, the best of which have added greatly to the potentiality of the crop.

Of velvet beans, there are now known about 15 species, and many varieties derived both by hybridizing and by mutation.

Japanese lespedeza consists of many varieties, as Essary of Tennessee has discovered, some of them far superior to the ordinary form.

The numerous species of *Melilotus* are also being carefully studied and at least one of them seems to be a decided acquisition.

FUTURE POSSIBILITIES

Even if one admits all that precedes, is it logical to expect any comparable results in the future? Let us view the subject broadly. There are known to botanists about 10,000 species of legumes and about 6,000 species of grasses. Of more than half of these, little is known except such characteristics as the dried specimen reveals. To assert that out of these enormous numbers none will be agriculturally valuable in the United States is highly improbable. Yet there is a constant tendency to magnify the importance of the knowledge now possessed, and to doubt that there is much more that will be discovered. Pertinent data on this aspect of the case will be presented later.

A second point deserves consideration. All of the tame hay and pasture lands of the United States are introduced plants, save only a solitary native, western wheat-grass. Corn, our most important forage plant, is of American origin; but, like all other plants cultivated

by the Indians, it is an intertilled crop. In studying the geographical origin of the hay and pasture plants now used in America, the following points are clear and the exceptions few. All northern hay and pasture plants originated in the region extending from Persia to eastern Europe. Practically all southern hay and pasture plants are of tropical or subtropical origin. California is much like the Mediterranean region, and probably 80 percent of the forage on California ranges is produced by plants of Mediterranean origin.

The Northwest Coast region is more like western Europe than any other portion of the United States. Many European plants which thrive aggressively there are almost unknown elsewhere in the United States.

Our great interior prairies and steppes resemble closely similar regions of central Asia. From thence come alfalfa and sweet clover; also the weeds Russian thistle, rosy saltbush, tumbling mustard, broncho grass.

The data are of importance as indicating where new plants are to be sought for use in any particular part of the United States.

A third point to be remembered is that plants useful for forage are very numerous. To be of value, a particular plant must be better than something already possessed. Indeed, a better forage may largely or wholly replace another, just as the sorghums replaced teosinte and pearl millet and as Sudan grass is limiting the usefulness of the millets.

A further point that must not be overlooked is that in all regions with a primitive agriculture, forage crops as such are not grown. The animals in such regions depend on crop refuse or on wild herbage or both.

RECENT INTRODUCTIONS

As bearing on the above considerations, the success with some recently introduced forage plants is pertinent. It may be easy to overrate the importance of a new plant until such is actually demonstrated by results, but this is inevitable. Only a few of the newer things are mentioned and several very new but very promising introductions are omitted.

Giant Bermuda Grass

There were obtained from Brazil living plants of a Bermuda grass that grows about twice as large as ordinary Bermuda. The preliminary tests showed that it yielded about twice as much as ordinary Bermuda, and this is borne out by the experience of Mr. A. P. Borden, of Pierce, Texas, who now has about 200 acres; Mr. James Bright, of Miami, Florida, and The Kicco Cattle Company, of Kicco, Florida,

each of whom have extensive plantings. In Hawaii also it is very productive. All this grass is propagated vegetatively, as the problem of producing seed is not yet solved. For this reason, the progress of the grass has been slow, but for many types of soils from Florida to Texas it would seem to be a grass of outstanding value. It is not at all hardy and probably will be of no value far north of the Gulf Coast.

Other Bermuda Grasses

After securing Giant Bermuda grass it was thought desirable to investigate other species. Of these, five have so far been secured. *Cyncdon incompletus*, the Bermuda of South Africa, looks very promising. Two species from Central Africa, *C. plectostachyus*, called "star-grass," and other species not yet identified, are without rootstocks and make even more luxuriant growth than Giant Bermuda. For southern Florida these last two seem to be great assets.

Korean Lespedeza

Many years ago, all the lespedezas obtainable were secured from Asia in the hope of finding relatives of Japanese lespedeza that were of comparable or greater value. The collection was very interesting botanically. In 1921, there was received a package of seed from Korea, which proved to be *Lespedeza stipulacea*, a species closely allied to *L. striata*, the so-called Japan clover. Two years' study of Korean lespedeza leads to the conclusion that it is a great find and will be to northern pastures what Japanese lespedeza is to southern pastures.

Mung Bean

The mung bean was very long ago introduced, but has never been of real importance, as both the cowpea and soybean are superior. The introduction of the Mexican bean beetle bids fair to make a revolution of the mung necessary. It is immune to the beetle, while the cowpea and soybean suffer severely. This factor may make it of much importance. It is a good forage plant with excellent seed habits.

Hungarian Vetch

In extensive experiments with species of vetch in Oregon, several have been found to be of much promise. Some years since, the vetch aphis proved very destructive to common vetch, but the Hungarian vetch is immune. This factor has made it important, but in itself it produces highly satisfactory yields of hay and of seed.

Bahia Grass

Some years ago there was introduced from Brazil this grass, *Paspalum notatum*, which is splendidly adapted to Florida and the

Gulf Coast region. It holds the ground persistently, but spreads very slowly. For some reason which is not yet clear, the seed is not very satisfactory. Recently, it was discovered that this grass is the common pasture grass of western Cuba, and it is strange that it did not become introduced into the United States a long time ago. In time, it will probably cover all the well-drained lands of Florida.

MOLASSES GRASS

This is the famous pasture grass of Brazil. Several years ago, experiments showed it to be well adapted in Florida on nearly all soil types, even sand hills, provided the soil was well drained. Unfortunately, in the original trials, cattle refused to eat the grass. Recent experiments have been highly successful both as regards the grass and the cattle. The latter must in many cases be taught to eat it—a parallel case to that of sweet clover. In the southern half of Florida, the grass produces abundant seeds, but the season is a little too short northward. This grass will undoubtedly prove of high value.

It will be noticed that a large proportion of these introductions are for the South. It is to be remembered that the North inherited its agriculture, particularly its forage plants, from Europe, and plants adapted to this zone have been far more studied than tropical or subtropical plants. Hence greater opportunities exist in the latter.

So far as the western lands are concerned, there is every reason to be hopeful that Central Asia, when agriculturally explored for grasses and legumes, will yield species that will be of great value, especially pasture plants. There is no reason why plants from Asia should not be relatively as valuable in the West as bluegrass and white clover are in the North, or Bermuda and lespedeza in the South. One Asiatic grass, namely crested wheat-grass, is already showing much promise. A thorough exploration of Central Asia for grasses and legumes is one of the things greatly to be desired.

7. THE FUTURE OF THE SOYBEAN AS A FORAGE CROP[1]

J. C. HACKLEMAN[2]

Before discussing the possibilities and probable future of the soybean, a comparatively new legume in corn belt agriculture, it seems advisable to review first the growth of all legumes and observe the general tendency.

[1]Paper read as part of the symposium on "The Forage Problem" at the meeting of the Society held in Chicago, Ill., November 12, 1923.

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Red clover is the most important legume, in point of seeded acreage, that is grown in the United States. It makes excellent pasture, is good for hay, and, under favorable conditions, is a highly valuable green-manuring crop. In that portion of the United States which is sometimes referred to as the red clover belt, there seems to be a distinct tendency toward smaller and smaller acreages of this important legume, with a corresponding increase in the amount of alsike. The explanation seems to be that it is getting more difficult to get a stand of red clover, consequently farmers are inclined to the use of alsike. This tendency is especially noticeable in mixed hay and pasture acreages. In the recent census approximately one-third of the hay and forage acreage in the United States is listed as clover and timothy mixed. This acreage was perhaps seeded with a mixture, but the tendency is in the direction of a pure culture of timothy by the time the harvest is reached.

The corn belt states and Minnesota, Wisconsin and Michigan have slightly more than 9.1 acres out of every 100 acres of improved land in legumes. Omitting the states of Michigan and Wisconsin from this average, there is slightly more than 6.4 acres of legumes per 100 acres of improved land. When it is understood that this average includes the annual legumes, as well as alfalfa, it must be apparent that the legume occupies too small a proportion of our cropped lands.

Table 1 gives the percentages of the different legumes to the total acreage of hay in the corn belt states as reported for 1900, 1910 and 1920.

TABLE 1.—*Showing percentages of legumes to total hay acreages in the corn belt states in 1900, 1910, and 1920.*

State	Timothy-clover mixed		Clover alone			Alfalfa			Annual legumes
	1910	1920	1900	1910	1920	1900	1910	1920	1920
Illinois	26.6	28.3	10.8	13.7	17.1	0.27	0.58	3.0	2.3
Indiana	20.9	33.1	31.8	13.3	16.8	0.03	0.87	3.1	0.9
Iowa**	60.7	55.2	3.2	4.1	8.8	0.02	0.72	5.5	0.2
Michigan	62.7	65.7	9.69	6.4	4.3	0.04	0.25	2.6	0.2
Minnesota	45.2	49.5	2.36	3.6	5.0	0.02	0.12	2.3	0.3
Missouri*	45.2	31.6	10.8	7.9	6.3	0.06	1.00	5.5	1.7
Ohio	31.9	39.3	20.40	5.6	8.2	0.09	0.92	3.1	0.1
Wisconsin	66.4	68.4	8.48	4.6	6.3	0.02	0.69	2.4	0.1

*Missouri had a 600,000-acre loss in the cultivated hay acreage; the mixed clover and timothy acreage was reduced by 650,000.

**Iowa had a 937,000-acre loss in the cultivated hay acreage; the mixed clover and timothy acreage was reduced by 741,000.

Throughout the corn belt, the dairy section of the north, and the

eastern portion of the United States, the general tendency toward more alsike clover, especially in mixtures, is largely traceable to the lack of lime. Since more than half of the tillable land of the twenty or more states in this general section is seriously in need of lime, the seeding of clovers becomes more and more precarious.

This was the condition prior to 1915. With the war and its consequent demands for increased food production, there came a still greater reduction in the legume acreage, until at the conclusion of the war in 1918 the legume had practically been crowded out of thousands of farms throughout the corn belt. With the readjustment of farming systems after the war, the legume naturally came in for consideration. Realizing the seriously depleted condition of the soil and, in addition, facing a demoralized world market, farmers began to listen more favorably to the recommendations of the various state agricultural colleges and the United States Department of Agriculture, and to search for and make more liberal use of the legumes that were adapted to their farming systems. With an already reduced limestone content in the soils of the region under discussion, the intensive grain farming during the war left these soils in a still worse condition at its conclusion. This, coupled with an unfavorable economic condition, made it necessary for many farmers to look for acid-tolerant legumes. The cowpea fits such a need, and has been popular throughout the cotton belt for many decades. The farmers of the corn belt, however, required a somewhat different legume, and consequently were ready and willing to adopt the soybean. The data for Illinois, shown in Table 2, may be considered typical of what happened generally through this section of the United States.

TABLE 2.—*Showing change in acreages of certain hay crops in Illinois.*

	1909 Acres	1919 Acres	1923 Acres
Clover alone	427,957	507,443	
Clover with timothy	827,625	837,833	
Alfalfa	18,344	88,968	136,000
Soybeans alone	300	3,288	229,000
Soybeans with other crops		36,000	426,000

The increase in the acreage devoted to the soybean crop each year since 1918 is nothing short of phenomenal. In fact, this is probably the greatest change in an agricultural practice in the history of corn belt agriculture. This remarkable increase is traceable to at least four factors. First, the campaign which had been conducted in all states to increase the legume acreage was beginning to bear fruits, and the farmers were looking for a satisfactory legume. Second, the oat crop seemed to offer less financial returns each successive season and became less popular throughout the corn belt, and the farmers

began to search for a substitute for this crop. Third, because of this phenomenal increase in acreage, seed production could not keep pace with the demand, and therefore prices were maintained at a comparatively high figure, making seed production attractive. Fourth, the comparatively few farmers who had been producing and using soybeans on their farms were finding them excellent feed and all reports of feeding trials at experiment stations had shown the crop to have great merit as a home-grown feed.

During this period of expansion little or no time was given to a fundamental study of the soybean crop to determine its real value and to ascertain its proper place in the farming system.

Considerable emphasis has been given the fact that this crop grows well on sour soils where clovers fail. While soybeans are quite acid-tolerant, it is nevertheless true that the crop responds readily to applications of limestone. This is shown by Table 3, which summarizes data from the soil experiment fields scattered throughout the state of Illinois, and indicates the response of the soybean to applications of agricultural limestone.

TABLE 3.—*Showing yields of soybean hay from different soil treatments on different soil types in Illinois.*
(Yields expressed as tons of hay per acre.)

Number of experiment fields	Soil type	Number of crops	Soil treatment: None	Manure	Manure-lime	Manure-lime-phosphate
2	Yellow gray silt loam (timber) ..	6	.69	.86	1.37	1.58
4	Gray silt loam on tight clay......	18	.70	.86	1.28	1.34
9	Brown silt loam...	27	1.43	1.61	1.70	1.81
1	Light gray silt loam on tight clay....	2	.85	1.10	1.58	1.54
1	Dune sand.......	6	.90	1.05	1.41	1.35

These data, gathered over a period of from three to ten years, are proof that while soybeans will make fair yields on acid soils, applications of limestone are beneficial to the production of this crop. The data in Table 4, also from the soil experiment fields in Illinois, show the beneficial effect of limestone in seed production of soybeans.

If the soybean is to be recommended to corn belt farmers, they should at the same time have their attention called to the amounts of lime used by this crop and the fact that applications of limestone are profitable. Table 5 shows the amount of limestone used per ton and per acre by some of the common legumes, under Illinois conditions. It is easily to be seen that the continuous growing of soy-

beans will rather rapidly reduce the lime content of an already sour soil.

TABLE 4.—*Showing yields of soybean seed from different treatments on different soil types in Illinois.*
(Yields expressed as bushels of seed per acre.)

Number of experiment fields	Soil type	Number of crop tests	Soil treatment: None	Residues	Residues and limestone	Residues limestone and phosphate	Residues limestone phosphate and potassium
11	Brown silt loam..	42	14.4[a]	15.7	17.1	18.8	18.9
6	Gray silt loam on tight clay......	62	6.0[b]	6.8	9.8	9.8	11.5
2	Yellow gray silt loam (timber)..	9	3.4	3.9	8.5	9.6	9.3
1	Yellow silt loam..	3	2.3	2.5	4.3	5.0	4.6
1	Yellow gray sandy loam.........	2	7.4	7.8	9.3	9.4	9.2
1	Light gray silt loam (tight clay)	6	5.1	6.0	9.8	10.2	10.4
1	Dune sand......	9	6.4	6.3	9.2	9.7	9.8

[a]Average of 35 tests.
[b]Average of 55 tests.

TABLE 5.—*Showing limestone required per ton and per acre for growth of various legumes in Illinois.*

Crop	Limestone required to grow one ton[a]	Estimated yield	Limestone required to grow one acre
	pounds	tons	pounds
Alfalfa hay....................	85	4	340
Red clover hay................	75	3	225
Alsike clover hay...............	60	2½	150
Sweet clover hay[b].............	70	2	140
Soybean hay...................	90	2	180
Cowpea hay...................	90	2½	225
Timothy hay...................	20	2½	50
Oat hay.......................	20	1½	30
Corn fodder....................	30	9[c]	270

[a]Wisconsin Agricultural Experiment Station Bulletin 312.
[b]Fall crop.
[c]60-bushel crop.

Much has been said about the merits of the soybean as a soil builder, and great promises have been made for it. However, it now seems certain that entirely too much emphasis has been given to this characteristic of the crop. There is no question but that the soybean, when properly inoculated, is of value as a legume and does manufacture considerable of its own nitrogenous food from atmospheric nitrogen when in a favorable environment. But investigations have disclosed the fact that a comparatively small percentage of the corn belt farmers who are producing soybeans are really raising the crop as a soil-improving legume. In other words, the question of inoculation is a very important one and must be considered, if the soybean

crop is to attain the place in corn belt agriculture that it now seems destined to occupy. Few farmers realize that an average soybean crop requires almost twice as much nitrogen as a good crop of oats. This fact forcefully emphasizes the necessity of thorough inoculation if money return per unit of plant food used is considered. Table 6 shows the comparative plant food requirements of an average crop of oats and an average crop of soybeans.

TABLE 6.—*Showing comparative plant food requirements of oats and soybeans.*

Crop (Seed only)	Requirements in pounds Nitrogen	Phosphorus	Potassium
Oats (60 bu.)	39.6	6.6	9.6
Soybeans (20 bu.)	77.0	10.0	18.0

In addition to the natural depletion of the soil under such conditions, the residual effect of this practice upon subsequent crops is a pertinent question. In the state of Illinois, the soybean seems to fit best into our farming system preceding wheat. When soybeans, without inoculation or when poorly inoculated, are grown on land of average fertility the resulting effect upon the wheat crop is frequently unfavorable. This condition, however, can be largely, if not entirely, overcome by more thorough inoculation and increased fertility. The summary of data bearing on this matter, from the Missouri, Ohio and Pennsylvania experiment stations shown in Table 7 are illuminating.

TABLE 7.—*Showing yields of wheat following oats and soybeans at different experiment Stations.*

	Missouri Bu. per acre	Ohio Bu. per acre	Pennsylvania Bu. per acre
Wheat after oats	21.0	34.7[a]	26.2
Wheat after soy beans	21.0[b]	34[c]	23.7

[a]Average of 21 crops
[b]Average of 6 plots.
[c]Average of 42 crops.

The Indiana experiment station has made a study of this problem, comparing the oat and soybean crops in a four-year rotation of corn, oats or soybeans, wheat and clover. Their observations to date indicate that wheat following soybeans yields approximately six bushels per acre more than when seeded after oats. In both of these rotations the wheat receives an application of complete fertilizer.

The comparatively few farmers who have grown soybeans and the workers at experiment stations who have fed them to livestock have testified to the value of the crop for hay; but its real importance has not been appreciated. Because of the comparatively high lime content, as indicated in Table 5, and its relatively high protein

content, soybean hay is one of our best leguminous forages. At first, the woody stems prejudiced growers and feeders against it, but they are now learning when to cut and how to handle the crop to make it more valuable and more palatable.

Up to the present time, the cost of production of soybeans has been too great and the seed market too active to stimulate the greatest utilization of the grain from this crop on the farm as home-grown supplement to other feeds. Production costs are being reduced, however, and farmers are learning to grow the crop with less labor and therefore more economically. The average cost of producing soybeans has been approximately $1.15 a bushel, compared with corn at 57c and wheat at 90c. This can probably be materially reduced.

Experimental data showing the great value of soybeans in livestock feeding are rapidly accumulating. Workers at the Indiana experiment station have found, in their swine feeding experiments, that ground soybeans, when properly supplemented with a mineral mixture, have practically the same feeding value, pound for pound, as tankage. The Iowa and Illinois experiment station workers have also reported favorably on soybeans as hog feed. Soybean seed is also valuable for dairy animals. McCandlish, of the Iowa experiment station, states that when oil meal is worth $45.00 a ton, soybeans are worth $60.00 a ton as a protein supplement for dairy cattle.

The general recognition by farmers of the value of both the hay and the seed will greatly stimulate the production of soybeans, especially in livestock sections, where stock are available to help harvest the crops. The reduction in cost of production will naturally provide home-grown nitrogenous concentrates at a lower figure, thus reducing the cost of producing farm animals. Frequently, it is not the cost of production, but the replacement value in terms of other products, that determines the real value of a crop on the farm.

Table 8 presents a comparison of the cost of production of soybean seed and hay with the value of the crop when used as a substitute for other feeds.

These data show clearly that the full value of soybeans can best be realized by feeding either the seed or the hay, or both, in a properly balanced ration. The crop offers one of the cheapest forms of protein available. Furthermore, experiments have shown that the soybean protein is perhaps the best of the plant proteins from the nutrition standpoint. As more information is made available regarding this important home-grown supplement, the crop will doubtless gain in popularity.

TABLE 8.—*Showing comparative feeding value of soybean products in terms of other feeds.*

Product	Cost per ton	Value in terms of other feeds: Tankage	Linseed oil meal	Cotton seed meal	Alfalfa
Soybean seed	$38.32	$39.00[a]	$52.60[c] 50.00[d]	$44.60[f] 62.00[g]	
Soybean oil meal	45.00	57.20[b]	50.00[e]	45.00[f] 65.20[g] 60.00[h]	
Soybean hay	13.60				$18.00[e]

[a]Summary of fourteen tests with 113 pigs (tankage $70.00, linseed oil meal $50.00).
[b]Summary of seven tests with 49 pigs.
[c]Summary of six tests with 31 pigs at Illinois, Indiana, Kansas, Kentucky and Ohio.
[d]Beef steers fed at Illinois, 1918–19.
[e]Sheep fed at Illinois, 1922–23 (alfalfa $20.00).
[f]Beef steers fed at Illinois, 1922 (cottonseed meal $50.00).
[g]Beef steers fed at Illinois, 1923 (cottonseed meal $50.00).
[h]Beef steers fed at Purdue University, average two years, 1922–1923.

During the season of 1921, when it appeared that soybean production had practically reached the stage where the annual increase in the acreage would no longer absorb the seed supply, it became necessary to look for other channels for disposal of the surplus seed, and commercial outlets were found. There are now several soybean oil mills in the central portion of the United States, which are ready to absorb any probable seed surplus that is created. This has a significant bearing on the livestock industry, especially pork production, since the amount of tankage is limited. In cattle production, the long haul necessary for cottonseed meal is costly, and this factor operates in favor of the locally grown bean crop. The soybean oil mills which are ready to operate in Illinois have a combined capacity exceeding 25,000 bushels per day, and those in Indiana probably half that. These mills found comparatively little seed available when they attempted to operate during the season of 1922. The same thing will be true for 1923–24, the seed demand will absorb the supply.

Summarizing, therefore, it would seem conservative to draw the following conclusions: First, that the acreage of soybeans will and should increase; second, that the most profitable outlet for the production will be as a seed crop and as a home-grown nitrogenous feed, substituting for the high-priced commercial concentrates; third, that applications of limestone to the soil must be recognized as essential to the most successful permanent production of soybeans; fourth, that, after sweetening the soil, more efficient methods of inoculation must be found; and, fifth, that legumes must be classified

more nearly on the basis of their special or particular values. Alfalfa is pre-eminently a hay plant; sweet clover the best for green manure and pasture; red clover for dual-purpose hay and pasture legume; and soybeans the best annual nitrogenous seed and hay-producing plant.

8. THE PROBLEM OF FORAGE CROPS IN RELATION TO SOIL IMPROVEMENT[1]

C. A. Mooers[2]

THE VALUE OF LEGUMES AS SOIL IMPROVERS

Few leguminous crops have been studied so thoroughly and over so long a period that data are available to show definitely what can be expected from them, either as to their effect on the maintenance of soil nitrogen, or as to their influence on the yield of succeeding crops.

Results from experiments conducted for the past eighteen years by the Tennessee experiment station show that either cowpeas or soybeans, when the crop is harvested for hay, usually exercise little influence on the crop following and are, in this respect, not comparable with red clover, alfalfa, or the like. In fact, strong evidence was obtained that a vigorous perennial grass, unaided by clover, is much better for the maintenance of soil fertility than either of these summer legumes. In a rotation of cowpeas and wheat on a fertile loam both crops being grown each year, that is, cowpeas in summer and wheat in winter, the turning under of the cowpea crop every year for the eighteen years has not maintained the soil supply of nitrogen and the yield of wheat has fallen off. In a cropping system of cowpeas one year and corn the next, continued for the same length of time (18 years), the turning under of the cowpea crop each year as grown was not sufficient to prevent a steady and decided decrease in the yield of corn. Where the cowpea crop was removed as hay the decreased yields of both wheat and corn were much more in evidence than where the crops were turned under as might be expected. These series of experiments, together with similar series continued from five to fourteen years in other parts of the state, have given important data on the influence of the cowpea crop on soil productivity, at least so far as loam soils of the character used are concerned. The question arises. however, would like results be obtained on either much lighter or much heavier types of soil? Another question is this, can the

[1]Paper read as a part of the symposium on "The Forage Problem" at the meeting of the Society held in Chicago, Ill., November 12, 1923.

[2]Director and Agronomist, Tennessee Agricultural Experiment Station, Knoxville, Tenn.

results obtained from the cowpea be applied to the closely related legume, the soy bean? There are some indications that they can not, save in a general way. A rather common complaint among farmers is that wheat following soybeans does not do as well as when following cowpeas. W. W. Garner of the United States Department of Agriculture, in his field experiments, found that soybeans exerted a decidedly unfavorable action on the following tobacco crop.

As soil improvers, leguminous crops are supposed to be chiefly valuable on account of the increased supply of nitrogen which they make available either directly or indirectly to succeeding crops. Results in Kansas and New York have indicated that total soil nitrogen may be no more than maintained under continued alfalfa culture. Is this an outcome to be generally expected, or would there result a nitrogen balance which would vary with the kind of soil? Experiments conducted on a poor soil at the Tennessee station placed alfalfa decidedly ahead of red clover, so far as the effect on the corn crops of the four following years was concerned. On the other hand, there appeared to be little or no difference between the two legumes, as measured by their effect on winter barley. Such results are suggestive, but further evidence is needed before definite conclusions can be reached.

Common observation shows wide differences between different legumes in respect to root development, including subsoil penetration. Lespedeza, producing two or more tons of hay per acre, can do so because of the multitude of plants, each one of which makes only a comparatively short and restricted growth, either of top or root. On the other hand, alfalfa giving a like yield may not require ten percent as many plants as the lespedeza, and its root development is evidently much more robust and the penetration far deeper. Marked differences between them, as measured by their effect on succeeding crops of non-legumes, would therefore be expected.

The comparative merits of various annual, biennial and perennial legumes as soil improvers appears to be a very promising subject for further investigation. In this investigation, soils of different character should be utilized. Differences not only in soil texture, but also in productivity, and in nature of subsoil, must be considered. As an index of fertilizer value not one crop, but several, should be used for the probability that unlike results will be obtained from such different crops as corn, cotton and tobacco, for example. In work of this kind, the duration and intensity of the after effects for a period of several years are important matters. If a long-continued and thorough study is to be made on a certain field, a record of changes in total soil nitrogen is very valuable.

THE INFLUENCE OF NON-LEGUMES ON CROPS THAT FOLLOW THEM

The influence of various non-legumes on the crops that follow them has received attention in this country, as well as abroad. The importance of a study of this subject was emphasized some years ago by H. J. Wheeler, at that time Director of the Rhode Island experiment station. For several years, it has been studied by Garner, with special regard to tobacco. One of the most pronounced results noticed by him was the bad effect of corn on any crop that followed. On the other hand, all kinds of crops did well after tobacco. These conclusions coincide with results obtained in farm practice; for "stalk-land" wheat is notoriously poor, but the wheat crop after tobacco is nearly always good. Investigations should be made with regard to various soil conditions, as indicated above in the case of the legumes. Also, in connection with experimental work of this kind, not only with legumes, but also with non-legumes, the reaction of the soil may well be taken into consideration. P. L. Gainey, of the Kansas experiment station, found that soils with a pH value of less than 6 seldom contained *azotobacter*, the non-symbiotic nitrogen-fixing organisms. It may be that apparently diverse crop-results can be explained on the basis that one soil supports a vigorous *azotobacter* flora whereas another is devoid of them.

CROP ROTATIONS SUITABLE TO LAND THAT SUFFERS FROM EROSION

Over large areas, especially in the southern states, erosion does great damage. It is severe when either a cultivated crop or a summer legume, such as cowpeas, is grown. There is opportunity for the obtaining of not only new, but also highly practical, information relating to cropping systems for land of this character. Under these conditions may it not be advisable to omit cultivated crops, even when it comes to our greatest forage crop, corn? What crops are best under such circumstances? Much more is known about crops as individuals than of crop successions and mixtures. This is an important subject in the South and the experiment stations are only beginning to consider it. In Tennessee, winter barley gives promise of being the best substitute for corn. There is even promise that, with the proper crop rotation, barley will produce more grain than is obtained from corn under present conditions. May not sweet clover, lespedeza, white clover and rescue grass be utilized in such a way that their reseeding will be done naturally and that the only soil preparation will be for the barley crop? It is practically self evident that drastic changes must be made in the cropping systems of some sections, or that erosion will be so severe that there will soon be no soil left on which crops can be grown.

BOOK REVIEWS

SOIL MANAGEMENT

By Firman E. Bear, Professor of Soils, Ohio State University, and Associate in Soils, Ohio Agricultural Experiment Station. John Wiley and Sons, Inc., New York. 268 pages. 1924.

The author of this book states that it is intended for use in a required course in soils in an Agricultural College. The book, for this reason, is elementary in the sense that it does not go greatly into detail or include the more technical phases of the relationships of the subject to other sciences.

The references cited are given at the ends of the chapters. More references to experimental work touching the subject matter of the various chapters would make the book of greater value to the more advanced student; but for the purpose for which the book was written, those given are probably sufficient.

The first third of the book deals especially with the relationships between soils and plants, the second third to various phases of soil management practice, while the last third has to do with manuring practices.

The author recognizes that the subject of soil management is not cut and dried but that many of our practices may change as more knowledge of the relationships between plant and soil is acquired. Something is therefore said of phenological relations of plants and soils and mention at least is made of ecological relations.

Altho written perhaps more from a chemical viewpoint, nevertheless, considerable is said concerning the biological relations between soils and plants. A brief chapter is also included under the subject "Soil Sanitation" which deals with toxicity, plant diseases, insects and weeds.

A large part of the section on manuring practice is given to commercial fertilizers and their proper selection with reference to soil, system of cropping and management, climate and finally economy. In reference to the latter subject, something is said concerning the recent movement toward high-analysis fertilizers.

Criticism might be made of the arrangement of subject matter but it must be recognized that this is one of the most difficult points in the presentation of a subject as broad as that of soil management.

As a whole, the book is suggestive rather than informative of detail and should find a place in the teaching of the subject.

Finally a good index is appended which is not the least which can be said of a book used for text or reference. (R. C. Collison.)

TEXTBOOK OF AGRICULTURAL BACTERIOLOGY

By F. Löhnis and E. B. Fred. McGraw-Hill Agricultural and Biological Publications, edited by C. V. Piper. McGraw-Hill Book Co., Inc., New York. 1923.

This is essentially a revision and translation of the "Vorlesungen

über landwirtschaftliche Backteriologie" of the senior author. It is divided into two principal sections, one on general morphology and physiology and one on dairy and soil bacteriology.

The book is unusually well illustrated by drawings, photographs, and nine colored plates. Many of these are taken directly from the original German edition, and lose somewhat in that labels are in German and not always intelligible to the student in agriculture. The material is well balanced, and emphasis well placed, although the statement that the two main objects of agricultural bacteriology are studies of bacteria in foods and in soil is perhaps too restrictive. If the student in agriculture pursues the subject no farther than the presentation in this text, many points of great importance to him will be missed. It is rather an introduction to general dairy and soil bacteriology than a text on the whole field of agricultural bacteriology.

On the whole, this text is undoubtedly the best in its field that has appeared. It should fill a real need. (R. E. B.)

A CORRECTION

In Table 1, page 72, of the January number of this JOURNAL (Vol. 16, No. 1), at the bottom of the page, for 65 read .65 and under $n = 24$ for this value read 356 instead of 256.

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EFFECT ON PERMANENT PASTURES OF TREATMENTS WITH LIMESTONE AND ACID PHOSPHATE AS MEASURED BY THE QUANTITY AND QUALITY OF THE VEGETATION PRODUCED[1]

EARL E. BARNES[2]

Very little experimental work on the effects of fertilizers on the vegetation produced on land used exclusively for pasture was done prior to 1897. Considerable work on meadow improvement had been undertaken previous to that time, but the results in these experiments were calculated purely on the basis of increased yields of hay. Little attention had been given to the changes in the chemical composition of the forage which resulted from the treatments.

REVIEW OF PREVIOUS INVESTIGATIONS

Somerville (4),[3] in 1911, reported the results of nine years of experimental work, on three different fields, where plots of 3 1/20 acres each were given various treatments. The effect of the treatments were measured by two methods. The first means of measurement was that of securing relative gains in weight of sheep pastured on the different plots. Three acres of each plot were utilized for this purpose. The second means of measurement was that of determining the weights and chemical analysis of hay harvested from 1/20 acre of each plot. This 1/20 acre was fenced off from the remainder of the plot. The fence was changed annually so that a different area was used each year from which to harvest the hay. This provision minimized as far as possible any change in the character of the pasture flora which might result from continued mowing instead of grazing. A significant fact, brought out in this experiment,

[1]Contribution from the Department of Soils, Ohio State University, Columbus, Ohio. Received for publication January 6, 1924.

[2]Assistant Professor in Extension Service.

[3]Reference by number is to "Literature Cited," p. 251.

was that the ratio between the gain in weight of sheep pastured on the several plots and the content of protein in the hay produced on the same plots was nearly constant for all the plots. This was especially true for those plots which received no nitrogenous fertilizer. This fact has an important bearing on the interpretation of the results, which were obtained in the work described in this paper. There was also a close agreement between the returns from the treatment, as measured by the weight of hay produced, and the gain in weight of sheep pastured on the same plot.

Ballou (1 and 2), of the Ohio Agricultural Experiment Station, in connection with work in orchard rejuvenation in southeastern Ohio, made some interesting observations on the effect of fertilizers on the amount and character of mulch material which the land produced. Table 1 gives the data bearing on this point, from one of these experimental orchards:

TABLE 1.—*Effect of fertilizers on the amount and character of vegetation.*

Annual fertilizer treatment Material	Pounds per acre	Yield in pounds per acre	Vegetation predominating
Acid phosphate	350	2,716	Red clover
Acid phosphate	350		
Muriate of potash	175	2,884	Red clover
Acid phosphate	350		
Muriate of potash	175		Blue grass and
Nitrate of soda	350	3,458	other grasses
Unfertilized	—	840	"Poverty grass" and weeds

The significant facts shown by the above data are the remarkable increase in the total amount of vegetation produced and the change in the predominating type from "poverty grass" to red clover, as a result of the use of acid phosphate. These changes came about without the sowing of any seed.

Greig (3), of the Aberdeen and North Scotland College of Agriculture, reports some pasture experiments in which the increases in the weights of sheep pastured on the plots were nearly doubled by applying either acid phosphate or basic slag to the soil at the rate of 1,000 pounds per acre, or by the use of 2 tons of lime per acre.

OBJECT OF THIS INVESTIGATION

Since the spring of 1920, about 400 pasture improvement demonstrations have been started in southeastern Ohio. Only one, under the supervision of the Department of Soils of Ohio State University, was under way at that time. In 1921, several more were started and, in 1922, a large number of pasture demonstrations, scattered over 11 counties, were begun. The treatments given these plots have con-

sisted, in general, of applications of limestone and acid phosphate, either with or without some tillage and seeding.

Until 1923, the only data relative to the effect of the treatments on these demonstrations were the estimates made by farmers of the percentage of desirable grasses and clovers before and after treatments. The averages of these estimates indicate that the pasture on the treated areas was from 200 to 300 percent better than that on the untreated areas. This method, however, is vague and inexact. More complete and more exact knowledge regarding the effects of these treatments on the quantity and quality of the vegetation produced is desirable. If in possession of these facts, one could more readily determine how much expense could be justified in the fertilization of permanent pastures.

The object of this investigation, therefore, was to determine the effect of an application of acid phosphate and limestone to pasture land, as measured by the amount and composition of the vegetation produced. This was measured in two ways; first, by comparing the amounts of crude protein, ether extract, ash, crude fibre, calcium, and phosphorus contained in the vegetation produced on the treated and the untreated parts of several demonstration fields; and second, by comparing the analyses of samples made up of the white clover plants produced on the treated and untreated portions of one of these demonstration fields.

METHODS EMPLOYED

Selection of Demonstration Fields

The fields were selected with the end in view of measuring the results of similar treatments in several counties having some variety of latitude and longitude. Consideration was also given to the length of time which had elapsed since the demonstration plot had been treated. Accordingly, fields were selected in Hocking, Jackson, Perry, and Guernsey counties, all in the state of Ohio. The plot in Hocking County was the oldest of the demonstration plots, and was chosen for that reason. The Jackson County plot was treated a year later and received no tillage or seed. The Perry County and the Guernsey County plots were both treated the same year and had almost identically the same treatment thruout their history.

Securing Samples

Early in the spring of 1923, three cages, each covering 1/4000 of an acre, were placed on each of the treated and untreated parts of four demonstration fields. The cages were built in the form of frames, which were 3.3 feet square and 18 inches high and were covered with wire netting of about 1½ inch mesh. Samples of the vegetation

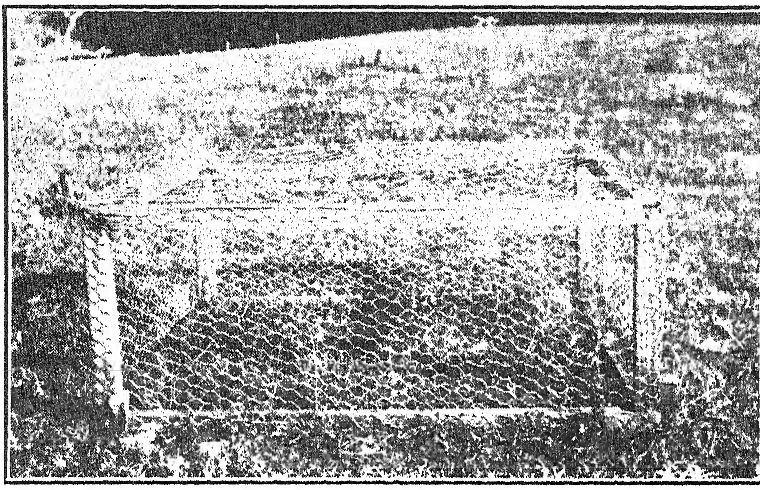

FIGURE 1—Showing cage for protecting sample areas from grazing and for sampling of vegetation.

were collected from the protected areas within these cages twice during the summer, by clipping the vegetation close to the ground with grass shears.

These samples were then sorted into two parts, one of which was composed of the leguminous and the other of the non-leguminous plants. The material was then dried and the weights of dry matter recorded. Later, the leguminous and non-leguminous parts were again mixed together and the growth for the entire summer was finely ground for analysis.

Two samples of white clover were taken at the time of harvesting the last cutting of vegetation from the Jackson County demonstration field. These were secured from the uncaged parts of the demonstration field, one from the treated portion and one from the untreated. These samples were dried and prepared for analysis in the same way as the other samples. The Jackson County demonstration field was the only one of the four on which legumes were to be found in conspicuous numbers on the untreated portion.

CHEMICAL ANALYSES

The total season's growths of vegetation, from both the treated and the untreated parts of each demonstration field, were analyzed for their content of moisture, ash, nitrogen, phosphorus, calcium, crude fibre, and ether extract. The same determinations were made on the samples of white clover except that the last two were omitted. The determinations of moisture, ash, nitrogen, crude fibre, and ether

extract were made by the use of the methods of the Association of Official Agricultural Chemists. Calcium was determined from the ash, and phosphorus from a separate sample which was oxidized in fuming nitric acid.

EXPERIMENTAL DATA

The following tables give the history of the plots and a record of the data secured:

TABLE 2.—*History of demonstration plots.*

County	Hocking	Perry	Guernsey	Jackson
Demonstrator	Kessler	Kelley	Jones	McCoy
Date of treatm't	Spring 1920	Spring 1922	Spring 1922	Spring 1921
Acid phosphate[a]	400 pounds	400 pounds	400 pounds	500 pounds
Limestone[b]	2 tons	2 tons	2 tons	1½ tons
Tillage	Soil disked	Soil disked	Soil disked	None
Seed[c]	15 pounds	15 pounds	15 pounds	None

[a]16% acid phosphate at rate indicated per acre.

[b]Finely ground limestone applied at the rate indicated per acre.

[c]Mixture of sweet clover, red clover, alsike clover, white clover, redtop, bluegrass and timothy, on all the plots seeded, at the rate indicated per acre. The Guernsey County plot had two pounds of Japan clover added to the mixture.

TABLE 3.—*Record of vegetation produced on treated and untreated areas.*[a]

Farmer	Plot	First Cutting Produce grams	First Cutting Legumes percent	Second Cutting Produce grams	Second Cutting Legumes percent	Yield in pounds per acre
Kessler....	Treated	727	56	863	1	4672
	Untreated	78	00	300	0	1111
Kelley.....	Treated	832	47	622	31	4275
	Untreated	260	00	150	0	1205
Jones......	Treated	892	30	671	46	4593
	Untreated	275	0	173	0	1314
McCoy....	Treated	799	11	65	0	2540
	Untreated	423	5	100	0	1537

[a]The areas harvested were 3/4000 acre each.

TABLE 4.—*Chemical composition of vegetation produced on treated and untreated areas.*

Farmer	Plot		Moisture	Ash	Crude fibre	Nitrogen	Phosphorus	Calcium	Ether Extract
Kessler....	Treated	(a)	5.28	8.46	22.54	2.45	0.236	1.06	2.45
		(b)	5.28	8.20	22.45	2.45	0.236	1.06	2.55
	Untreated	(a)	5.61	7.31	23.56	1.58	0.145	0.95	2.80
		(b)	5.69	7.33	23.87	1.58	0.143	0.82	2.64
Kelley.....	Treated	(a)	5.50	8.26	24.40	2.17	0.197	1.15	2.92
		(b)	5.57	8.33	25.04	2.18	0.195	1.18	3.11
	Untreated	(a)	5.48	8.19	23.42	1.63	0.214	0.84	2.94
		(b)	5.49	8.28	23.08	1.64	0.210	0.86	2.96
Jones......	Treated	(a)	5.37	8.45	27.42	2.18	0.223	0.80	2.79
		(b)	5.27	8.44	25.82	2.19	0.225	0.80	3.03
	Untreated	(a)	5.50	6.65	31.19	1.43	0.179	0.29	2.45
		(b)	5.54	6.72	31.73	1.43	0.182	0.29	2.50
McCoy....	Treated	(a)	3.97	10.06	29.03	1.51	0.176	0.88	2.70
		(b)	3.89	10.11	28.74	1.51	0.172	0.88	2.70
	Untreated	(a)	4.19	8.69	24.38	1.52	0.143	1.00	3.33
		(b)	4.34	8.72	25.56	1.51	0.141	0.99	3.38
McCoy[a]...	Treated	(a)	5.25	12.05	——	3.09	0.225	1.40	——
		(b)	4.29	12.09	——	3.08	0.228	1.40	——
	Untreated	(a)	4.44	12.65	——	2.79	0.234	0.83	——
		(b)	4.72	12.65	——	2.81	0.232	0.85	——

[a]Samples of white clover taken from treated and untreated parts of the demonstration field.

HOCKING COUNTY EXPERIMENT

This field is located in Marion Township, Hocking County, and lies midway between Bremen and Logan. It is on a steep hillside, so steep in fact as to make tillage of any kind practically impossible. The soil type would probably be classified as a stony phase of Dekalb, altho this area has never been mapped. Before treatment, this field produced no desirable vegetation and in many spots the ground was bare. Erosion was starting and the pasture presented anything but a prosperous appearance. The treatment was given in the spring of 1920, as indicated above. Of all the seeds sown, the only one to make any signfiicant growth was sweet clover. The amount of this seed sown in the mixture was insufficient to make a good stand. Some areas in the field were too acid, even after liming, to be favorable to this plant. On these areas, white clover began to creep in during the second season after treatment. The sweet clover reseeded itself at the end of the second year, and in the summer of 1923, which was the fourth summer after treatment, there was a good stand of sweet clover, on a large portion of the field. Two of the cages were placed on that portion of the field which was growing sweet clover. The other cage was placed on that portion of the field where white clover was the predominant legume.

The first cutting of vegetation was made on May 29th, 1923. The sweet clover at that time was just beginning to grow thru the covering of the cages and was at such a stage as is considered satisfactory for hay making. It was cut as near to the ground as was thought safe, without danger of killing the plants. The second cutting was made on the 10th of October. Owing to a very dry summer, the sweet clover did not make much second growth, but with the coming of fall rains, the bluegrass, which was interspersed with the sweet clover, thickened up so that a dense turf of this grass covered the ground at the time of the second cutting. Very few leguminous plants were present in the second cutting, in contrast to the first cutting, which was more than half leguminous. By multiplying the calculated yields per acre by the percentage of protein in the material, it was found that 715 pounds of crude protein per acre were produced on the treated plot as compared with 109 pounds per acre on the untreated portion. Thus the treated portion of the field produced, in round numbers, 4½ times as much total vegetation and 7 times as much crude protein per unit area, as did the untreated portion. If, as is indicated by Somerville's work, the amount of crude protein produced is a measure of the carrying capacity of a pasture, then the treated portion was 600 percent better than the untreated.

PERRY COUNTY EXPERIMENT

This field is located one-half mile east of Glenford. It lies near the top of a rather steep hill. The soil type would probably be classed as DeKalb silt loam. Before treatment this field produced very little vegetation except "poverty grass" (*Danthonia spicata*) and briars. The untreated portion of the field is still in this condition. The treatment was given in the spring of 1922. Enough tillage was given to cut off the briars and to root up most of the "poverty grass."

The first cutting on this plot was made on July 6, 1923. Of the total vegetation on the treated portion of the demonstration, 46 percent was leguminous and consisted of a mixture of red clover and white clover, the red clover slightly predominating. The second cutting was made on September 29th. In this cutting, 31 percent of the vegetation was leguminous. Red clover still predominated, but there was a visible increase in the proportion of white clover. The untreated portion of the field contained no legumes of any kind. The treated portion of the field produced, in the two cuttings, 582 pounds of crude protein per acre, and the untreated portion 124 pounds. If the carrying capacity of the pasture be measured in terms of the crude protein produced, the treated area had 370 percent greater carrying capacity then the untreated. The vegetation from the treated portion contained, pound for pound, 38 percent more calcium than did that from the untreated area. Thus from the standpoint of the mineral content of the vegetation, the pasture on the treated area was vastly superior.

GUERNSEY COUNTY EXPERIMENT

This field is located one-half mile south of Old Washington on the Lore City road. The topography is rolling, but with no steep slopes. The soil type is probably a DeKalb silt loam. The herbage was very scant before treatment, many places being entirely bare. The treatment was given in the spring of 1922; hence the summer of 1923 was the second summer after treatment.

The first cutting of vegetation was made on July 6, 1923. In this cutting, nearly 30 percent of the vegetation was leguminous. The leguminous portion was composed mostly of red clover and white clover with a small amount of alsike clover. The second cutting was made on September 28th (See Figures 1 and 2). In this cutting, 46 percent of the vegetation on the treated area was made up of legumes. The leguminous portion of this cutting was predominantly Japan clover. At the time of the first cutting, this plant had not attained sufficient size to affect the percentage of legumes. The total crude protein produced per acre, on the treated portion of this

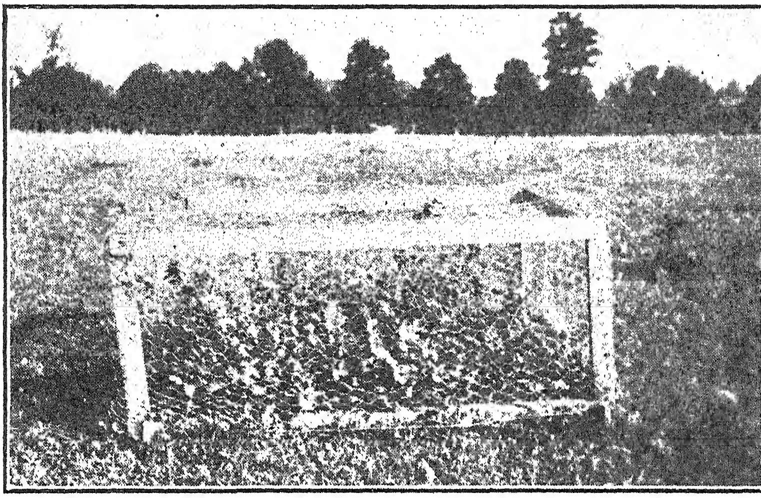

FIGURE 2—Showing legume vegetation growing on protected area of treated land on September 28, Guernsey County experiment. Compare with Figure 1, untreated land.

demonstration field, was 629 pounds, and on the untreated portion, 118 pounds. Thus, measuring the carrying capacity by the amount of crude protein produced, the treated portion was 430 percent better than the untreated. The percentage of calcium contained in the vegetation from the treated portion was nearly three times as great as that contained in the vegetation from the untreated portion.

JACKSON COUNTY EXPERIMENT

This field is located 12 miles southwest of Jackson, on the Maybees Pike. It lies on a gently sloping terrace, the soil of which would probably classify as a Holston silt loam. This was the only field, among the four, which produced any legumes of consequence on the untreated part. The plot was treated in the spring of 1921, and no tillage or seed was given it. In the spring of 1922, the treated plot was covered with an excellent stand of white clover. In the latter part of the season, Japan clover covered it in a thick mat. The field was chosen from among others in Jackson County, because it was the third summer since treatment and because it represented a treatment with limestone and acid phosphate without tillage or seed. When the plot was visited for the purpose of erecting the cages, it was found that moles had burrowed just beneath the surface of the soil during the winter, to such an extent that the surface was badly loosened. A little later it was discovered that this had killed practically all the white clover which had been such an excellent stand

the year before. However, it was then too late to change to another field, and hence this plot was carried thru the season as originally planned.

The first cutting was made on August 10, 1923. An earlier cutting had been planned, but owing to the fact that the white clover had been killed the previous winter, there was little growth of any kind on the plot until midsummer, when the Japan clover had made some growth. At the time of this cutting, the Japan clover was from 4 to 6 inches tall on the treated part of the demonstration field and about half as large on the untreated portion. The caged areas were clipped with grass shears and unfortunately it was found at the time of the second cutting on October 10, that the clipping had killed the Japan clover. In fact, there were practically no leguminous plants on the caged parts of either the treated or untreated portions of the field at the time of the second cutting. Outside the caged areas, the Japan clover was making an excellent growth. It is probable that if only one cutting had been made on this demonstration field, and this had been delayed until late September or early October, the results for the summer would have been much more favorable to the treated area.

At the time of the last cutting on this field, samples of white clover were collected from the uncaged portions of both the treated and untreated areas. The plants from the untreated area were very small and immature. In fact, they were so small that it required nearly four hours to collect enough to make 20 grams of air dry material. Those from the treated area were much larger and more mature.

Even with all the disadvantages which the treated portion suffered, it produced 65 percent more total protein per acre than the untreated. The most significant part of the investigation on this demonstration field is the effect which the treatment had on the nitrogen and calcium content of the white clover plants. The white clover on the treated portion, altho more mature, contained 10.4 percent more nitrogen and 74 percent more calcium than that from the untreated portion.

SUMMARY

The data of this investigation of the effects of treatments of acid phosphate and limestone on pasture land were secured by ascertaining the yield and chemical analysis of the total vegetation on small areas (3/4000 acre each) of both treated and untreated parts of the same pasture field. Four fields, each located in a different county, were included in the investigation. Three of the four received some

tillage and seed in addition to acid phosphate and limestone. One field received no tillage or seed. This field, owing to injury to the sod by moles during the winter previous to the summer when the records were taken, did not show as much improvement as the other three, but this cannot be taken as being due to the absence of tillage and seed. Two cuttings were made on each field during the season. The material harvested was dried and weighed and the percentages of legumes in each cutting was determined. It was then mixed together again and prepared for analysis.

Another phase of the investigation was the determination of the effect of treatments of acid phosphate and limestone on the analyses of an individual species of legume. White clover was the legume selected for this purpose.

The total vegetation produced per acre on the treated portions of these pasture fields, was from three to five times as much as was produced on the untreated portions of these fields except in one case where the sod had been injured by moles during the previous winter. The amount of crude protein produced per acre was from five to seven times as much on the treated as on the untreated portions of these fields.

The vegetation on the demonstration fields (Guernsey County) which had a large amount of Japan clover in the turf, showed a greater percentage gain in both calcium and phosphorus content, as a result of the treatment, than did the vegetation on the demonstration field (Perry County) of the same number of years standing, but containing no Japan clover in the turf.

The vegetation on the demonstration field (Hocking County) which had a large amount of sweet clover in it, was found to contain, as a result of the treatment, much larger percentages of both calcium and phosphorus than did that on the untreated area.

Where the principal legumes were red clover and white clover, the treatment did not materially influence the percentage content of phosphorus in the herbage, but did greatly augment the amount of vegetation produced.

CONCLUSIONS

The immediate effect of treatments of limestone and acid phosphate on "worn out" pastures in southeastern Ohio is a marked increase in the percentage of legumes. This is later followed by a renewal of the bluegrass sod, which does not reach its optimum until at least the end of the fourth summer after treatment.

The greatest difference in chemical composition between the

vegetation produced on treated and untreated portions of the same field is found to be in the percentage content of nitrogen.

The percentage increase in the content of calcium in the vegetation as a result of an acid phosphate and limestone treatment is greater than the percentage increase in its content of phosphorus.

LITERATURE CITED

1. BALLOU, F. H. Mulching the apple orchard. Ohio Agr. Exp. Sta. Mo. Bul. 1:313–18. 1916.
2. ———. Orchard rejuvenation in southeastern Ohio. Ohio Agr. Exp. Sta. Bul. 301. 1916.
3. GREIG, R. B. Report on the improvement of hill pasture as determined by effect on stock. Aberdeen and North Scotland College of Agriculture, Bul. 16. Abstract in Exp. Sta. Rec., 24:71. 1911.
4. SOMERVILLE, WM. Influence of manures applied to pastures on the production of mutton. Supplement to Jour. Bd. Agr. (Eng.) V. 17, No. 10, Jan. 1911.

THE EVALUATION OF CORN SILAGE[1]

F. A. PEARSON AND W. L. GAINES[2]

INTRODUCTION

The price of feeds is established, as a rule, by free sale transactions. The price of silage, however, is an exception to the general rule and its value must be established by other means.

Corn silage has come to be an important feeding stuff in our animal husbandry. It rivals pasture itself as a feed. Silage is perhaps especially important in the dairy industry, where it supplies from 20 to 50 percent of the nutrients in the ration. On a nutritional basis, in the more important dairy districts of Illinois, it represents about one-third of all the feed used in milk production, excluding pasture. An equitable basis of setting a price on silage is therefore a matter of importance. The question of how silage may be evaluated frequently arises in adjustments between landlord and tenant; in

[1]At the time the original material of this paper was prepared the senior author was on the staff of the Illinois Agricultural Experiment Station. Publication was delayed in part, because the cost data in terms of dollars underwent such marked changes as a result of the war; and in part, because further work is needed to round out and complete the idea and recommendation of the paper. Now, in 1923, however, the costs in terms of dollars are not so greatly different than at the time the data were collected. Further, the authors are not now in a position, at least cooperatively, to undertake the experimental work necessary to complete and round out the method of evaluation of corn silage as recommended. Consequently the paper is offered at this time for what it may be worth intrinsically and suggestively. Received for publication January 10, 1924.

[2]Professor of Agricultural Economics, Cornell University, and Professor of Milk Production, University of Illinois, respectively.

computing the commercial cost of production of animal products; and in placing economic interpretation on the results of experimental feeding trials. The values placed on corn silage at different times and by different people have not been very consistent. The extent and degree of such inconsistency has been well indicated by Whisenand (1).[3]

The peculiar position of silage in having no market value is due primarily to its rapid deterioration when exposed to the air, which makes it impractical of handling thru the regular channels of trade. There are, to be sure, occasional farm sales of silage, but they are too few in number and too uncertain of occurrence to be depended upon as an index of value. Silage must be stored at harvest in a building of special construction (silo), and after the silo is opened, the silage must be used from the top at a certain minimum rate, day by day, to prevent undue loss by spoilage. It cannot be hauled in quantity and successfully stored for future use. Consequently, the demand at farm sales is limited to a few immediate neighbors. Silage is high in water content and of comparatively low value per ton, which qualities also operate against its transport. Practically, silage must be stored near the harvest field and utilized very close to the place of storage. It follows, then, that the value to be used for silage must be determined by some rule, rather than directly by trade.

Two methods of evaluating corn silage are presented in this paper:

(1) *Cost Accounting Method.* This method starts with the corn crop at the time it is ready to harvest for silage and charges against the silage the value of the corn grain, the value commonly assigned to stalk[4] pasture, and the expense of harvesting and storing the crop as silage, together with some minor credits and debits.

(2) *Nutritional Method.* This method starts with the cured silage and involves converting it into terms of similar feeds which have established market value, on the basis of the digestible nutrients contained in the feeds concerned.

COST ACCOUNTING EVALUATION

In Table 1 are shown the items entering into the cost accounting evaluation. The data of this table are from records kept by Illinois farmers in cooperation with the Department of Dairy Husbandry, University of Illinois, and are thought to be representative of conditions affecting the cost of silage in the dairy districts of Illinois at the time. The period recorded covers the five seasons of 1912 to

[3]Reference by number is to "Literature Cited," p. 260.

1916, inclusive. Sixty-eight farms contributed to the data. The total silage acreage was 1,725 and the tonnage, 9,847. Measurements of acreage and weights were made in a few cases, but for the most part, the yields of silage and grain are estimates made by the farmer and other competent judges. Losses in the silo after harvest are not considered.

The account starts with the crop at the time it is ready to harvest for silage. This starting point is justified on the ground that only a very small percentage of the corn acreage in the United States (3.7 percent, as given in the 1921 Census) is used for silage; consequently this use of the crop can have only small effect on the market value of corn. At the time of harvest the farmer is entitled to the same returns on his silage acreage as he would receive if he harvested for grain, and charge to the silage is made accordingly.

The value for the grain was based on the farm value of corn, which of course was determined by the general market. The average farm value of corn for these years, as taken from the farm inventories, was $.6458 per bushel, and represents new corn in the crib rather than old corn. From this figure was deducted the cost of husking and cribbing, estimated at $.0525 per bushel, giving a value for the grain in the field at the time of harvest of $.5933 per bushel. The estimated yield of the total acreage (1,725) was 48,313 bushels of corn. The field value of the grain, therefore, was $28,664. Some corn is broken off in the field in harvest and does not reach the silo, and the amount of this was estimated at 2,977 bushels and was given a credit value of $1,693. The silage was therefore chargeable with 45,336 bushels of corn valued at $26,971, or $.5949 per bushel. The value of the stalk[4] portion of the crop was taken at $1.25 per acre, this being, by general consent among farmers, a fairly well established value for stalk pasture. The grain and stalk values together give the value of the crop. These and other charges are given in Table 1.

The several other items of charge listed in the table are largely self explanatory. The rate of farm man-labor charge averaged $.17 per hour and farm horse-labor $.125 per hour. The item of farm man and horse labor includes the time of the farmer's regular working force, both on his own job and in exchange work with neighbors, in the silage harvest. The item of extra man and team labor is in part for day labor and in part for man and team labor hired on a cash basis for the emergency.

The building charge consists of depreciation as shown by inventory

[4]The term "stalk" is used in this paper to refer to the stover portion of the corn crop, that is, all the crop except the grain (kernels).

values, and of interest at 5 per cent on the cost of the silo. Power and fuel include the hire of ensilage cutter, engine, and engineer, usually at a fixed cash rate per hour, the fuel being furnished by the farmer. Steam power was used in the majority of cases. The power item indicates the rate of filling to be slightly less than 5 tons per hour.

The farm equipment charge is for the use of machinery of all kinds except that included under power. The item of twine is for that used in harvesting with the corn binder. (Some farmers cut the corn in the field by hand, using no twine.) Insurance covers the silo and silage.

As shown in the table, the total value of silage as figured by the cost-accounting method is $4.53 per ton. In studying the distribution of this value between the several items, the second column, showing the percentage of the total, gives perhaps the clearest general

TABLE 1.—*Evaluation of corn silage by cost-accounting method.*
Summarized data of 68 farms—1,725 acres 1912–1916
Average yields per acre: 5.71 tons silage; 28 bushels corn
Average corn in silage: 4.6 bushels per ton

Item	Percentage of total value of silage	Total amount	Total value	Value per acre	Value of silage per ton
Total corn crop	65.32	9,847 tons	$29.127	$16.89	$2.958
Grain	60.49	45,336 bu.	26.971	15.64	2.739
Stalk	4.83	7,958 tons[a]	2.156	1.25	.219
Man and horse labor	19.88	......	8.865	5.14	.900
Farm man labor	9.24	24,143 hrs.	4.118	2.39	.418
Farm horse labor	8.32	29,703 hrs.	3.710	2.15	.377
Extra man & team labor	2.32	2,035 hrs.	1.037	.60	.105
Buildings	6.21	......	2.767	1.60	.281
Power and fuel	5.51	......	2.458	1.42	.250
Power	4.56	2,046 hrs.	2.034	1.18	.207
Coal	.71	1,852 cwt.	.315	.18	.032
Gasoline	.17	430 gals.	.078	0.5	.008
Kerosene	.05	292 gals	.023	.01	.002
Oil	.02	22 gals.	.008	.00	.001
Farm equipment	2.22	......	.993	.58	.101
Twine	.78	3,547 lbs.	.347	.20	.035
Insurance	.07	......	.030	.02	.003
Miscellaneous	.01	......	.003	.00	.000
Total	100.00	......	$44.590	$25.85	$4.528

[a]Estimated on basis of grain containing 60 percent dry matter, that is, weighing 83 1/3 pounds per bushel.

view. In descending order of the proportionate cost the items are: crop, 65 percent; man and horse labor, 20 percent; buildings, 6 percent; power and fuel, 6 percent; farm equipment, 2 percent; all else, 1 percent.

The crop is by far the largest item in the cost of silage, and of the crop the grain is valued at more than twelve times the stalk. Corn is not harvested as silage, however, either to facilitate the harvest of the grain or to enhance its feeding value. The grain is harvested

with the stalks solely because there is no practical way of handling it separately at the time of silage harvest. All charges, outside those for the grain, therefore, are to be regarded as the cost of securing the stalk portion of the crop as silage. On this basis, 40 percent of the cost of the silage is chargeable to the stalk, and 60 percent to the grain. As will appear below, this proportion is very close to the proportion of the nutrients supplied by each.

EVALUATION BY THE NUTRITIONAL METHOD

For reasons which are well recognized, the science of animal nutrition distinguishes the two general classes of feeds—concentrates and roughages. For exactly the same reasons, and also because the farm value of nutrients tends to be higher in concentrates than in roughages, corn silage is here treated as a mixture of concentrate (corn grain) and roughage (corn stalk). Corn silage has been commonly regarded as a roughage because of the bulk of the feed as a whole. There is good reason to suppose, however, that a bushel (that is, 50 pounds of dry matter) of the corn grain in corn silage is the equivalent in feeding value of a bushel of shelled corn. No direct experimental nutrition work has been done with the grain of corn silage. Somewhat roundabout, but still rather definite, evidence on the point is afforded by the experiments of Cook and Hills (2) of Vermont and Woll (3) of Wisconsin. The same method was used in both experiments, as follows: Two equal and like areas of corn were harvested at the same time. One was cut as silage in the usual manner, stalks and ears together (whole silage). The other area was first husked, and the stalks were then cut into the silo (green stover silage), while the ears were preserved by air drying. The ears were later ground and fed with the green stover silage. The resulting products of the two methods of harvest were compared as to their feeding value for milk production. The two experiments each showed a slightly greater value for the whole silage.

The nutritional method of evaluating corn silage starts with the proposition that the grain present in the silage is comparable with and equal to the same number of bushels of air-dry shelled corn, that is, 4.6 bushels per ton in the present case. The remaining part of the problem is to convert the non-grain, or roughage part of the silage, into terms of a comparable feed having market value. Hay is selected as such a feed, and conversion is based on the digestible nutrients contained in it. This basis of conversion is justified on the ground that digestible nutrients are commonly used in the science of nutrition to measure the relative nutritive values of similar feeds. An average is used of five common farm hays, largely from the grasses, as follows:

timothy, prairie, red top, clover and timothy, and red clover.

From this point on it becomes necessary to resort to analytical data from outside sources. The average analyses of corn silage ("recent analyses") and hay as compiled by Henry and Morrison (4) are used.

According to their figures, one ton of corn silage contains 354 pounds of digestible nutrients, and 4.6 bushels of corn contain 221 pounds of digestible nutrients. The difference, 133 pounds, is taken to represent the amount of digestible nutrients in the stalk portion of one ton of silage. The amount of each of the above hays required to furnish 133 pounds of digestible nutrients varies from 250 to 288 pounds, the average being 270 pounds.

For the purpose of evaluation by the nutritional method, therefore, it is concluded that one ton of silage in the present work is equal to the value of 4.6 bushels of corn plus the value of 270 pounds of hay.

It will be apparent that this conclusion is based on average analyses of corn silage, assuming a distribution of nutrients between grain and stalk portions as required by the yields of grain and total crop in the present work. This gives 62 percent of the nutrients in the grain and 38 percent in the stalk. This distribution is in substantial agreement with data given by Henry and Morrison (4, p. 195) showing for the corn crop 63 percent of the total nutrients in the ear and 37 percent in the stover.

To convert these results to money value, the prices of corn and hay are applied to the respective amounts above indicated. The average farm value of corn was \$.6458 per bushel and of hay, \$12.01 per ton, as shown by the accounts. The value of the silage, therefore, would be \$2.97 for the grain and \$1.62 for the roughage, or a total of \$4.59 per ton.

DISCUSSION

Formula for evaluation of corn silage. The value of a ton of corn silage as determined by each of the two methods as described above, is:

Cost-accounting valuation = \$4.53 per ton.

Nutritional valuation = \$4.59 per ton.

This would indicate that the two methods of evaluation give substantially like results.

In deriving a formula for the evaluation of corn silage, the cost method is not capable of any simple and comprehensive expression. The nutritional method is capable of concise and accurate expression. Further, freely marketable feeding stuffs tend in trade to take values in proportion to their nutritive qualities. The nutritional method, therefore, gives a value which it may be expected that silage would

assume in trade if it were freely marketable. The writers prefer and recommend the nutritional method of evaluation.

Practically, it may be said that hay contains 50 percent of digestible nutrients. As a general expression, then, the value of a ton of corn silage may be computed by the formula:

$$XC+2YH$$

in which X = bushels of corn per ton of silage; C = farm value of corn per bushel; Y = pounds of digestible nutrients in the non-grain portion of the ton of silage; and H = farm value of hay per pound.

Application of formula. The values to be used for C and H offer no particular difficulty. They may be had with reasonable definiteness from the market reports of farm values of corn and hay respectively. The values to be used for X and Y offer more difficulty. For the average of the silage in the present work $X = 4.6$ and $Y = 133$, assuming the average digestible nutrient content of the silage to be the same as the average given by Henry and Morrison. Probably these values may be safely used as, for example, Ross, Hall and Rhode (5) have used them, in dealing with the average of a number of lots of silage. Caution must be used in applying the average values to any particular case.

The value of well preserved corn silage is determined largely by two factors: (1) The percentage of dry matter, and (2) the proportion of the dry matter which is present as grain. Silage is so variable in these two qualities that the average figures found above for X and Y are limited in their value for specific application. In the silage reported in Table 1, the grain content ranged from 2 to 8 bushels per ton. The dry matter content of the silages, on which the average analysis is based, ranged from 12 to 42 percent.[5] Hence it is apparent that the values for the factors X and Y must be determined for each lot of silage to be evaluated, if the results are to be most satisfactory.

Determinations of X and Y. The value of X may be determined from the acre yields of silage and grain by weighing the crop as harvested, and leaving a few representative rows standing in the field for harvest of the grain. From the yield of grain by the check rows the acre yield may be computed, and thus the bushels of grain per ton of silage.

A laboratory method for the direct determination of the dry matter content and grain content would be very useful. The dry matter

[5]Prof. Morrison has kindly supplied the references for these analyses. Of the analyses available to the authors, 119 in all, the mean percentage dry matter content is $26.88 \pm .33$; standard deviation, $5.29 \pm .23$; coefficient of variability $19.68 \pm .89$. This variability is very high. It is hardly permissible to apply a mean value to a particular variant when the variability is as great as this.

may, of course, be determined by the official chemical method. The writers have attempted to adapt the Brown-Duvel (6) moisture tester apparatus and method to silage. The work done appeared promising for the success of the method, but it is left unfinished. A difficulty lies in securing a small sample of silage which is representative. A large cork borer may be used to advantage here. With it a cylindrical core may be cut to a depth of several inches from the surface of the silage in the silo. Workers at the Illinois experiment station are using satisfactorily a larger instrument of similar principle, which cuts a core 3.57 cm. in diameter, (10 sq. cm. cross area) and up to 100 cm. in depth for the sampling of silage and other coarse feeding stuffs (9).

Direct determination of the grain content of silage is a much more difficult problem. Mechanical separation of the grain and stover completely enough to give accurate results as to the proportion of each appears impractical. It is possible that chemical differentiation may be used, on the basis of some constituent occurring exclusively, or nearly so, in either the grain or stover. Starch is a possibility in this respect, since the grain contains a large percentage of starch and, according to Jones and Huston (7), from ten to twenty times the amount of starch in the accompanying stover. Thus, a starch determination on a sample of silage and on a sample of grain separated from the silage could be made the basis of estimating approximately the grain content of the silage.

Another possiblity is that the grain content may be estimated from the percentage dry matter content of the silage under certain conditions. This is given some promise by the data of Myers, Love and Bussell (8). Table 2 prepared from their data indicates a very high correlation ($r = .960 \pm .003$) between percentage grain content and percentage dry matter content of silage. The line of regression is obviously very nearly linear and an equation expressing the mean relation between the two variables could be easily derived. A corelation of .96 would justify the use of such an equation, at least for approximate work. The estimation of grain content might thus be greatly simplified.

It should be noted that the results quoted in Table 2 were obtained from small experimental plots. The data refer to the crop at time of harvest. Their "silage" is not ordinary silage, from the standpoint of method of harvest or curing. Their "dry grain" and "dry matter" appear from the text to mean air-dry material. Their data are, therefore, only suggestive with respect to the relation between dry matter and grain content in silage, as harvested and stored in practice.

TABLE 2.—*Correlation of the variables percentage "dry grain" content and percentage "dry matter" content in corn "silage."*[a]

Percentage "Dry Grain" Content—Class Mid-Points.

Percentage "Dry Matter" Content—Class Mid-point	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	Total
13	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
15	6	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	9
17	7	12	7	—	—	—	—	—	—	—	—	—	—	—	—	—	26
19	1	4	14	8	—	—	—	—	—	—	—	—	—	—	—	—	27
21	1	1	6	24	9	1	—	—	—	—	—	—	—	—	—	—	42
23	—	—	2	6	15	5	—	—	—	—	—	—	—	—	—	—	28
25	—	—	—	2	15	14	1	—	—	—	—	—	—	—	—	—	32
27	—	—	—	—	4	12	6	—	—	—	—	—	—	—	—	—	22
29	—	—	—	—	1	7	5	3	—	—	—	—	—	—	—	—	16
31	—	—	—	—	—	—	—	4	2	—	—	—	—	—	—	—	6
33	—	—	—	—	—	1	2	3	2	—	—	—	—	—	—	—	8
35	—	—	—	—	—	—	1	1	—	3	—	—	—	—	—	—	5
37	—	—	—	—	—	—	—	1	3	2	—	—	—	—	—	—	6
39	—	—	—	—	—	—	—	—	2	1	—	—	—	—	—	—	3
41	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
43	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	2
45	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1
47	—	—	—	—	—	—	—	—	—	—	—	1	1	—	—	—	2
49	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
51	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
53	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
55	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	2
Total	16	19	30	40	44	40	15	12	9	6	2	1	3	0	0	1	238

$r = .960 \pm .003$.

[a]Data from Cornell Agr. Exp. Sta. Bul. 408.

As a further refinement in the use of the nutritional formula for the evaluation of silage it would be desirable to know the digestibility of the grain and stover portions of silage separately. Data as to this seem to be entirely lacking; although, there are, of course, considerable data on the digestibility of silage as a whole. Sufficient grain could readily be separated from normal corn silage for determination of digestiblity. It is not feasible, however, to separate a representative portion of the stover portion without including any grain. The digestibility factor for the stover portion would probably be closely approximated by that of green stover silage. Until such time as experimental data are obtained it is necessary to assume digestibility factors for the grain and stover portions of silage in applying the formula for evaluation.[6]

[6]The digestibility of corn silage as a whole must be greatly affected by the proportion of grain dry matter and stover dry matter in the silage. Henry and Morrison give the digestibility of the dry matter in dent corn as 90 percent, that in corn stover as 57 percent, and that in corn silage as 66 percent. In feeding trials where the digestibility of the silage is not determined it should, obviously, be estimated in accordance with the proportion of grain and stover, The majority of the reports of feeding trials with silage, however, give no inkling that the grain content of the silage has been given any consideration.

SUMMARY

Two methods are used in this paper to evaluate corn silage:

(1) A cost accounting method, in which the silage is charged with the value of the corn crop in the field at the time of silage harvest, the cost of harvest, storage, etc.; (2) a nutritional method, in which the silage is converted into terms of shelled corn and hay on the basis of digestible nutrients, and the market values of these feeds are then used to evaluate the silage.

The first method is illustrated with data from cost accounting records kept on sixty-eight Illinois farms during the seasons 1912 to 1916, inclusive. The total silage acreage was 1,725 and yield 9,847 tons, containing an average of 4.6 bushels of corn per ton. The method gave an average value of $4.53 per ton.

The data for the second method depend in part upon the averages of the published analyses of corn silage. The average ton of silage above was converted into terms of 4.6 bushels of corn plus 270 pounds of hay. Applying the average farm values of corn and hay for the seasons mentioned gave a value for the silage of $4.59 per ton.

The corn-plus-hay evaluation of silage (per ton) is recommended by use of the formula, $XC+2\ YH$, in which X is bushels of corn per ton of silage; C is the farm value of corn per bushel; Y is pounds of digestible nutrients in the non-grain portion of the ton of silage; and H is the farm value of hay per pound. The values for C and H are to be had from market reports. The data given indicate an average value of 4.6 for X and 133 for Y. But corn silage is so extremely variable in grain and dry matter content, that the actual value for X and Y should be used, if possible, for the particular lot of silage to be evaluated.

LITERATURE CITED

1. WHISENAND, J. W., Factors in the cost of corn silage. *In* Proc. Am. Soc. of Animal Production, 1919:87-92.
2. COOKE, W. W., and HILLS, J. L., Sixth An. Rpt. Vt. Agr. Exp. Sta. 1892: 163-199.
3. WOLL, E. W., Ninth An. Rpt., Wis. Agr. Exp. Sta. 1892:53-71.
4. HENRY and MORRISON, Feeds and Feedings, 15th Ed., Henry-Morrison Company, Madison, Wisconsin. 1915.
5. ROSS, H. A., HALL, H. F., and RHODE, C. S., The feed cost of milk and fat production as related to yields. Ill. Agr. Exp. Sta. Bul. 244. 1923.
6. DUVEL, J. W. T., A moisture tester for grain and other substances and how to use it. U. S. Dept. Agr., Bur. of Pl. Ind. Circ. 72. 1914.
7. JONES, W. J. and HUSTON, H. A., Composition of maize at various stages of its growth. Ind. Agr. Exp. Sta. Bul. 175. 1914.
8. MYERS, C. H., LOVE, H. H., and BUSSELL, F. P., Production of new strains of corn for New York. Cornell Agr. Exp. Sta. Bul. 408. 1922.
9. GAINES, W. L., A roughage. sampler. *In* Jour. Ind. and Eng. Chem., 16: 386-387, 1924.

DEVELOPMENT OF WHEAT PLANTS FROM SEMINAL ROOTS[1]

Lowell F. Locke and J. Allen Clark[2]

NORMAL DEVELOPMENT OF WHEAT ROOTS

There normally are two sets of roots which support the growth of

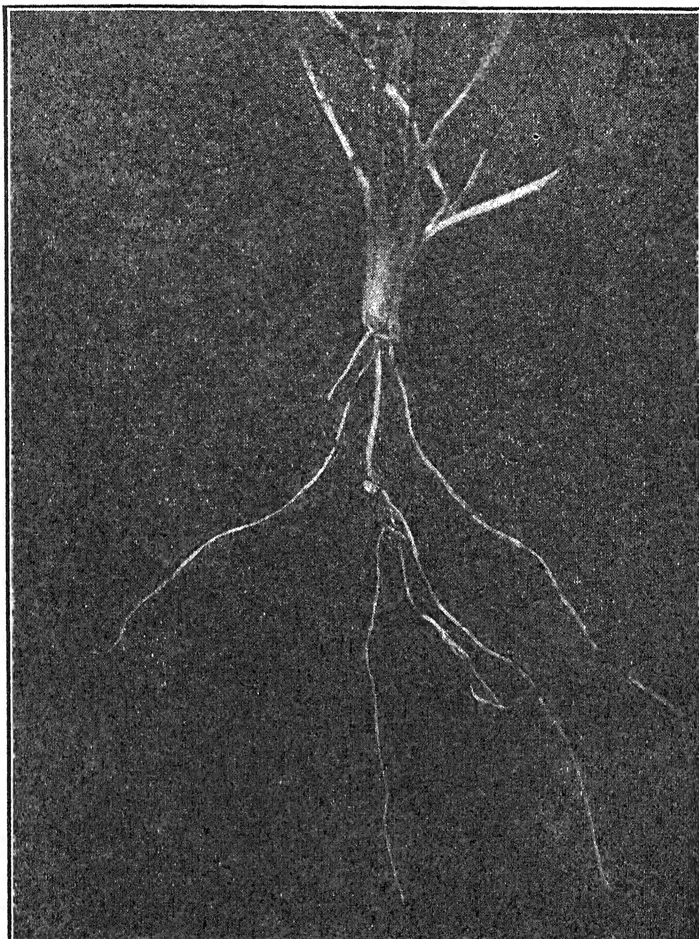

Fig. 1—Young wheat plant, showing development of the crown and permanent roots from the end of the elongated mesocotyl, some distance from the seed.

[1]Contribution from the Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C. Received for publication, February 1, 1924.

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the wheat plant. The first, the seminal or seedling roots, are produced by the young plant as it develops from the seed. The second, the coronal or permanent roots, arise from the crown usually just below the surface of the ground. The crown also is the place of origin of the shoots produced by the seedling. The distance between the seed and the crown varies with the depth of seedling.

When seeds are sown near the surface the crown is formed at or but little above the seed. When seeds are sown deeply, the plumule is pushed upward and the crown still is formed near the surface. (Fig. 1). That part of the plant between the seed and the crown is the mesocotyl, an underground stem which also has been called the subcoronal internode. Under field conditions this may vary from less than one inch to three or four inches in length and has about the diameter of a pin.

In normal growth, the young wheat plant is nourished by the endosperm contained in the kernel and from the seminal roots through this mesocotyl until the secondary or coronal roots are formed at the crown. The latter then provide for the further development of the plant. These roots greatly surpass the seedling roots in number and size.

OBSERVATIONS ON DELAYED ROOT DEVELOPMENT

Two instances are known to the writers where physical conditions prevented or delayed the development of the secondary or coronal roots and the wheat plant continued to be supported in its growth by only the seminal roots at the base of the mesocotyl or underground stem. In spite of this condition, the leaves, stems and even spikes and seeds developed.

In semiarid and arid sections of the western United States, moisture usually is the principal limiting factor in wheat production. The total amount of precipitation received is important, but not so vitally important as the distribution during the crop year. The abnormal, or delayed, development of root systems here reported is due principally to the time, nature and amount of precipitation.

Observations at Nephi, Utah, in 1919

At and about Nephi, Utah, Aaron F. Bracken, superintendent of the Nephi Substation, made observations on the winter wheat crop of 1919. Table 1 shows the dates and amounts of precipitation at the Nephi Substation from July, 1918, to June, 1919, inclusive.

In 1918, the precipitation was slightly below normal for September and October, but above normal for November. Even though the precipitation was below normal, the soil was moist enough to produce almost perfect germination.

The winter followed with the amount of precipitation below normal every month. The soil remained frozen, with the exception of about

TABLE I.—*Dates and quantities of precipitation from July 1, 1918, to June 30, 1919, at the Nephi Substation, Nephi, Utah.*

July		August		September		October		November		December	
Date	In.	Date	In.	Date	In.	Date	In.	Date	In.	Date	In.
6	.26	15	.02	5	.33	3	.09	2	.06	4	.52
10	.09	28	.04	15	.02	4	.66	7	.10	5	.29
11	.26			23	.66	7	.05	10	.52	6	.01
13	.64			24	.09	16	.07	12	.37		
14	T			30	.06	17	.09	13	.09		
15	.21							14	.12		
20	.20							25	.36		
22	.10										
23	.01										
	1.77		.06		1.16		.96		1.62		.82

January		February		March		April		May		June	
Date	In.	Date	In.	Date	In.	Date	In.	Date	In.	Date	In.
23	T	15	.21	4	.10	7	.35	6	.04		
		28	.46	5	.15	8	T	9	.04		
				7	.15	11	.10	10	.10		
				14	.16	13	.11	22	.22		
				15	.24	21	.19	30	.47		
				16	.08						
				27	.07						
	T		.67		.95		.75		.95		.00

three inches on the surface. As the frozen layer stopped the natural downward movement of the water, the surface was completely saturated. April began with warm weather and an unusual amount of wind. This, aided by the low rainfall, dried the surface of the soil into an extremely hard crust.

The plants which emerged before winter formed the crown near the surface of the soil. Under the abnormal spring conditions most of the plants were not able to develop permanent roots, due to the thick crusts. The first or seed roots sustained the plants.

The precipitation for April and May was below normal and in June there was not even a trace of moisture. During the last week of June, when the wheat was beginning to mature, high temperature and high winds caused a rapid ripening of the wheat. Many of the plants, which had never developed permanent roots, were blown over during the wind storms, resulting in serious losses. Figure 2 shows a picture of a winter wheat plant which developed to maturity at the Nephi Substation from moisture obtained by the seminal roots and transmitted through 3 to 4 inches of mesocotyl or underground stem, surrounded by dry crusted earth in which no permanent roots developed.

OBSERVATIONS AT WOODWARD, OKLAHOMA, IN 1922

Winter wheat in the district about Woodward, Oklahoma, is sown mainly in September. From a glance at the precipitation record

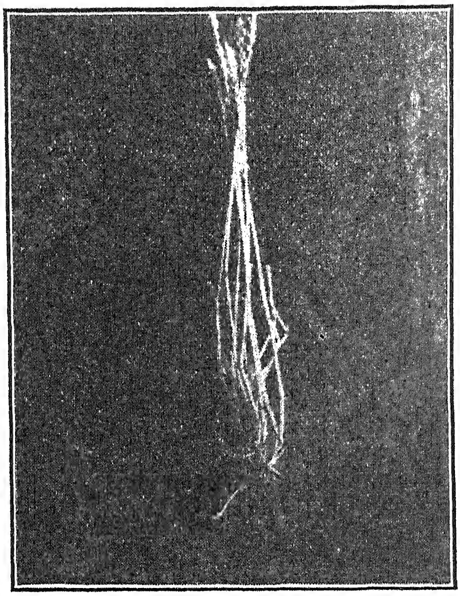

FIG. 2—Plant of winter wheat which developed to maturity at Nephi, Utah, in 1919, from moisture obtained by seminal roots and transmitted through the hypocotyl or underground stem to the crown. (Photographed by J. A. Clark.)

for the latter half of the year 1921, it is evident that so little rain fell in that season as to make conditions unfavorable for germination and growth.

Immediately after the rain of 2.80 inches on September 7, a very large acreage of wheat was sown and came up to a good stand. Very little of it, excepting in favored spots, formed any but the seminal roots during the fall. Despite this, it made a fairly vigorous top growth. Despairing of its ever making a paying grain yield, a few farmers had turned stock in upon it and many more had concluded to do so "in order to get what they could out of it." Lightly rooted as it was, stock entirely destroyed it in a very short time.

On the Field Station, it was decided to water small plats to determine the results that farmers might expect if fall rains came. The reaction to watering, even lightly, was favorable, the wheat making permanent roots with great rapidity. As an outcome of this

TABLE 2.—*Dates and quantities of precipitation from July 1, 1921, to June 30, 1922, at the Woodward Field Station, Woodward, Oklahoma.*

July		August		September		October		November		December	
Date	In.	Date	In.	Date	In.	Date	In.	Date	In.	Date	In.
5	.63	2	T	7	2.80	1	T			2	.04
10	.28	9	.22	12	.03	6	T			3	.02
11	.94	11	.74	17	T	7	T			5	T
18	.19	12	2.45	18	.10	29	.01			6	.03
24	.42	13	1.49	19	T	30	T			7	.02
25	.04	14	.21	24	.01					8	T
		15	T							15	T
	2.50		5.11		2.94		.01		.00		.11

January		February		March		April		May		June	
Date	In.	Date	In.	Date	In.	Date	In.	Date	In.	Date	In.
3	.04	14	.05	1	T	1	T	1	.01	1	.06
9	.84	21	.21	8	.50	2	.41	7	2.60	16	.06
10	.05	25	T	9	.56	3	.03	8	T	24	.05
13	.03	26	.05	11	.04	4	.09	10	.32	27	.01
19	T	27	.25	12	.83	5	.01	14	.26	30	T
22	T	28	.40	13	2.22	6	.50	15	.05		
24	T			14	T	7	.29	21	.46		
28	T			18	.04	8	.10	22	.02		
30	.01			19	T	13	T	26	T		
31	.05			24	.51	23	.82	27	T		
				25	.02	24	.04	28	T		
				30	.36	25	.06	29	.14		
						26	.16	30	T		
						27	.04	31	.09		
						28	.01				
						29	T				
						30	.41				
	1.02		.96		5.08		2.97		3.95		.18

experiment, the results of which were published locally, thousands of acres were saved from destruction by grazing and, rains finally coming, the wheat at harvest made paying yields.

As conditions similar to those experienced may prevail again, a study of the experience at Woodward should be of value. Such a study can be made from the following photographs and tables with very little explanation.

The plants shown in Figure 3 grew on plats one yard square, sown about September 20, and (with the exception of group A, which was not watered) watered with a sprinkling pot on November 26 at the following rates in acre-inches: group B, .25; group C, .50; and group D, 1 inch. The plants were photographed on December 5, only nine days after watering. Root growth varied with the quantity of water applied, but showed great response to even a small amount.

The photograph shown as Figure 4 was taken on January 31, after .89 of an inch of rain had fallen on January 9 and 10. Plants from Plat A are shown on the left, and from Plat D on the right.

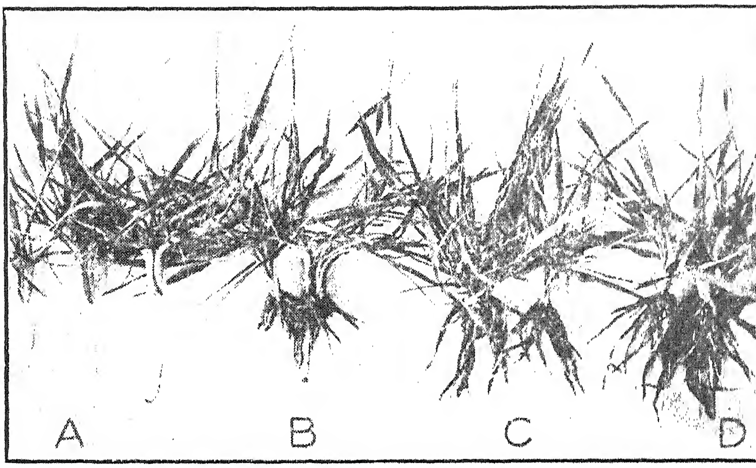

Fig. 3.—Young wheat plants grown at Woodward, Okla. (A) not watered; B, C, and D irrigated on Nov. 26, with .25 inch, .50 inch, and 1.0 inch of water per acre, respectively. (Photographed on Dec. 5, 1921, by Lowell F. Locke.)

The watered plants had made much the greater growth, but the unwatered plants had responded well also, although they had remained

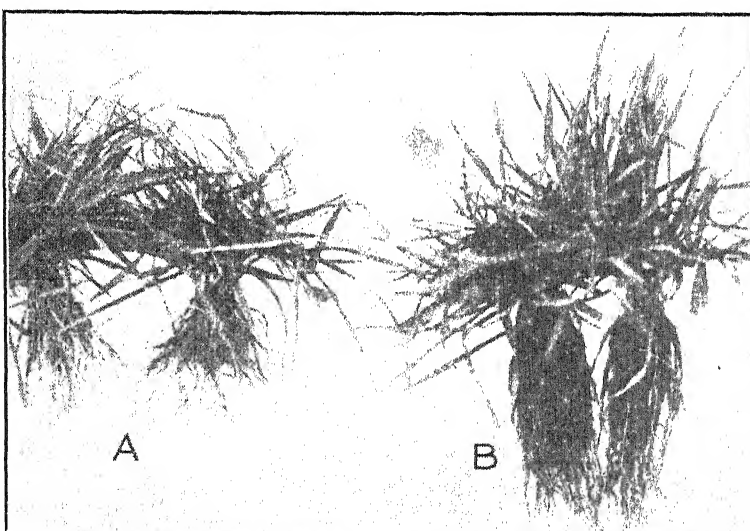

Fig. 4.—Plants taken from the plats represented by group A and group D of Fig. 3, showing on Jan. 31, 1922, the growth of unwatered (A) and watered plants (B), after .89 inch of rain, which occurred January 9 and 10. (Photographed by Lowell F. Locke.)

practically at a standstill, as shown by Group A, in Figure 3, until rains fell in January, a period of over three months.

The soil moisture conditions throughout the season are of interest and suggest explanations for the peculiar condition of the wheat, which was previously unheard of in this section. No moisture data are available from the plats cropped to wheat, but there are an abundance from those cropped to rye. Samples were taken on November 26 from rye plats, all of which were sown in September. They contained percentages of soil moisture, shown in Table 3.

TABLE 3.—*Percentages of moisture in upper and second six-inch soil layers of rye plats at Woodward, Okla., on November 26, 1921.*

Layer sampled	Plat A Plowed Sept. 23 3 in. deep	Plat B Plowed July 22 8 in. deep	Plat C Fallowed
Upper 6 in.	1.9	2.3	2.6
Second 6 in.	4.8	5.0	5.0

The data do not indicate how very dry and dusty were the two or three inches at the surface, but they do show that the top soil was very dry, while a few inches below there was enough moisture to suport considerable growth. In this soil, which is sandy, the percentage of moisture rarely exceeds 9 percent, and often is as low as 2 percent before plants die.

Table 4 shows percentages of moisture in samples taken from the same plats to the depth of six feet throughout the cropping season.

TABLE 4.—*Percentages of moisture in each of the first six one-foot soil layers of rye plats at Woodward, Okla., on nine different dates during the growing season for the 1922 crop.*

Depth in feet	1921 9/24	1921 10/1	1921 11/26	1922 4/1	1922 4/15	1922 5/6	1922 5/20	1922 6/13	1922 6/20
			Plat A. Plowed 3 inches deep on Sept. 23.						
1	4.8	4.6	3.5	10.8	9.2	9.2	8.2	3.4	3.1
2	4.4	4.7	4.1	8.7	8.9	8.9	8.6	6.1	5.3
3	3.9	4.2	3.6	9.1	9.1	8.0	7.7	5.4	5.6
4	3.4	3.4	3.2	8.0	7.6	7.7	7.7	6.1	5.2
5	3.6	3.0	3.5	6.6	8.5	7.7	8.0	5.4	5.0
6	2.4	2.4	2.5	6.0	6.3	7.7	7.2	4.8	4.7
			Plat B. Plowed 8 in. deep on July 22.						
1	8.4	7.7	3.7	9.6	7.9	7.0	5.5	3.3	2.8
2	8.1	7.8	5.4	8.3	8.7	6.2	5.5	4.2	3.6
3	8.1	7.8	6.1	8.0	7.9	5.7	5.5	4.7	4.4
4	8.3	8.2	7.6	8.3	8.1	7.2	6.4	5.8	5.1
5	7.7	7.9	7.3	8.1	8.3	8.8	7.7	6.3	5.0
6	7.6	7.7	7.6	8.7	7.8	8.2	7.3	6.0	5.9
				Plat C—Fallowed.					
1	8.7	8.5	3.3	9.2	7.4	6.0	4.4	3.1	2.6
2	8.4	7.8	4.5	9.1	9.3	5.6	5.3	4.0	3.8
3	7.8	7.5	5.0	6.8	7.5	6.5	4.8	4.1	3.9
4	8.7	9.6	8.2	8.6	8.8	8.0	6.3	5.6	5.1
5	8.6	9.2	7.6	7.9	7.8	6.8	6.9	7.2	5.8
6	8.3	8.3	7.0	8.9	8.6	7.0	8.0	5.6	5.8

The yields of grain from these rye plats were as follows:

Plat	A	B	C
Date planted	9/24/21	9/24/21	9/24/21
Date harvested	6/20/22	6/14/22	6/14/22
Yields, bushels per acre	7.9	10.3	28.2

The yields of winter wheat on plats treated exactly the same as the rye plats, in which moisture content was determined, and adjacent to them, were as follows:

Plat	A	B	C
Date sown	9/23/21	9/23/21	9/23/21
Date harvested	6/20/22	6/13/22	6/13/22
Yields, bushels per acre	13.3	27.2	34.5

SUMMARY

Under normal conditions two kinds of roots are developed by the wheat plant. The first are seminal, or seed, roots and the second are coronal, or permanent roots. In two different instances, physical conditions have been observed to prevent or delay the development of the permanent roots. At Nephi, Utah, in 1919, packing, drying and crusting of the soil prevented normal development of the permanent roots. At Woodward, Okla., in 1922, extremely dry surface soil prevented penetration of the permanent roots. Under these conditions, the seminal roots furnished sufficient moisture to maintain the growth of the wheat plant to maturity, or until rains occurred and permanent roots developed normally.

WINTER HARDINESS OF MEDIUM RED CLOVER STRAINS[1]

A. C. Arny[2]

In round numbers there were imported into the United States, in 1919, 1920, 1921, and 1922, red clover seed in the amounts of 7, 12, 16, and 10 millions of pounds, respectively, largely from France, Italy, and Chile. In 1923, only half a million pounds were brought in. This year, due to the short clover crop in the United States, which is estimated at 78.1% as compared with the 1922 crop (1),[3] an unusually large amount is likely to be imported, in view of the fact that the crop, in Europe particularly, was better than usual.

Data presented by Wiggans (2) show that, under New York

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[2]Professor of Agronomy and Head of the Section of Farm Crops, Division of Agronomy and Farm Management.

[3]Reference by number is to "Literature Cited," p. 278.

conditions, stands of clover secured from the use of Italian red clover seed winterkilled 95%, from French seed, 20%, and native seed Michigan grown 10%. The yield of hay from the stand secured from using Italian seed was 334 pounds per acre as compared with 6,635 pounds per acre from stands secured from native seed and 5,966 pounds from French seed. In another publication (3) data presented show yields on a percentage basis f r Italian and French seed to be 4 and 76, respectively, as compared with 100 for Michigan-grown seed.

For Michigan, Megee (4) has found plants from Italian red clover seed winterkilled 50% or more. From the first cutting, a yield of 1.32 tons of hay per acre was secured from the plots sown with Italian seed, 2.85 tons from native seed, and 2.46 tons from French seed. There was no second cutting from the plots planted with Italian seed and a poor second crop from the French seed, as compared with a good second crop from native seed. Second growth is important in clover for pasture or plowing under for green manure.

Data presented by Pieters (5) show that Italian, French, and Chilean seed is not adapted for use in the northern states.

EXPERIMENTAL WORK

Technique of the Work

In the spring of 1922 seedlings of medium red, mammoth red, and alsike clovers were made on quadruplicate plots (four strains were sown in duplicate only, because of lack of sufficient seed) 5 feet wide and 132 feet long, with alleys 1 foot wide between each two plots. The seed was secured for the most part through the cooperation of Dr. A. J. Pieters, in charge of Clover Investigations, Forage Crop Investigations, Bureau of Plant Industry, United States Department of Agriculture. The clover seed was evenly distributed by hand at the rate of twelve pounds of good seed per acre on each plot. The plots were then harrowed lengthwise and oats drilled crosswise. The oats were cut for hay, in order that the stands of clover might not be injured by any possible lodging. Good stands were secured for all strains with the exception of that from Wisconsin. The stand for this strain averaged 82.5%. Red clover seed from Wisconsin is the equal in every respect to seed secured from other northern states, but this particular sample proved to be low in germination. In early May, after the large majority of the injured or killed plants had become discolored or nearly dry, so as to be easily distinguished from the uninjured ones, the number of plants in three square yards (4) in each plot was counted. The number of the live and dead, or badly injured, plants was recorded. From these counts the percentage of winterkilling was computed.

When the clover had reached the proper stage of development for hay, the produce of each entire plot was weighed green and a shrinkage sample taken, which was permitted to become air dry. The air-dry samples were then dried in a steam heated oven to constant weight. These weights were increased by 15% to give weights comparable to air-dry weights of hay.

WEATHER CONDITIONS

The winter of 1922–23 was approximately normal for Minnesota as compared with others for several years back. The minimum temperatures, together with the maximum recorded, are given in Table 1.

Light freezing of the ground took place in late November and early in December it froze solid and remained in this condition up to the latter part of March. During the latter part of March the ground thawed to a depth of 3 inches. After this it froze again and remained so until April 12. During January and February and the first part of March the ground was covered with snow. During the latter part of March and first part of April there was no snow. The lowest temperatures recorded for the winter season were −15° F. for December and −7°, −27° and −17° respectively for January, February, and March.

On January 2, a careful examination of a number of plants of each strain was made. Many plants were found in the Tennessee, Italian, Chilean, and French strains which were brown in the central portion of the root for six to eight inches down. Other observations were made at intervals and it is thought the plants were killed chiefly during the cold weather between December and March and not during the alternate thawing and freezing of the latter part of March and the first part of April.

During May and June the rainfall was slightly above normal. Therefore, there was ample moisture for the first cutting of hay. During July and August the rainfall was approximately 50% of normal which was not sufficient for a good second cutting.

RESULTS OF THE TESTS

In Table 2, there are given the data on the original stands, the number of plants killed during the winter, the percentage of winterkilling in each plot, and the average for each strain and the yields of hay on a 15% moisture basis. An examination of the data for stands shows that there were with only one exception more plants per square yard on the first plot of each strain than on the third or fourth. This is due to the fact that the first and second plot of each strain

TABLE 1.—*Maximum and minimum temperatures together with total precipitation and precipitation as snow from October 1, 1922 to April 30, 1923, at University Farm, St. Paul, Minn.*
(Temperatures expressed as degrees Fahrenheit)

Month	Maximum temperature recorded	Number of days with minimum temperature for period October 1 to April 30 inc.								Lowest temperature recorded	Precipitation	
		33° or above	32° to 23°	22° to 13°	12° to 1°	0° to −6°	−7° to −12°	−13° to −18°	Below −18°		Total inches	As snow inches
October	85°	25	6	0	0	0	0	0	0	30°	1.08	Trace
November	64°	17	13	0	0	0	0	0	0	24°	3.70	1.5
December	51°	0	8	7	7	3	5	1	0	−15°	0.18	2.0
January	42°		1	6	21	2	1	0	0	−7°	1.12	12.9
February	45°		1	3	4	6	5	6	3	−26°	0.50	6.4
March	48°		6	6	12	4	1	2	0	−17°	1.33	14.0
April	70°	13	13	3	1	0	0	0	0	7°	2.20	11.0

TABLE 2.—*Comparison of stands, percent winterkilling and yields of stands secured from strains of medium and mammoth red clover from the leading clover seed-producing areas.*

Kind of clover	Number	Source	Plot no.	Counts of clover plants on three square yard areas on the given number of plots of each variety: Total plants	Living plants	Dead plants	Killing	Average winter-killing	Yeilds of hay per acre on a 15% moisture basis: First cutting	Second cutting	Total
							%	%	Tons	Tons	Tons
Strains from North Central and North Intermountain States											
Alsike	....	Minnesota	1	805	783	22	2.7				
			71	561	492	69	11.8				
			101	480	479	1	0.2	4.9	1.58	....	1.58
Mammoth	....	Minnesota	2	445	418	27	6.1				
			72	485	412	73	15.1				
			102	366	360	6	1.6	7.3	1.15	....	1.15
Altaswede (Mammoth)	....	Canada	5	614	582	32	5.2				
			75	488	437	41	10.5				
			105	483	463	20	4.1				
			19	581	464	117	20.1	10.0	1.09	....	1.09
Medium	2221	Wisconsin	6	302	286	16	5.3				
			76	179	166	13	7.3				
			106	184	175	9	4.9	5.8	0.88	0.54	1.42
Medium	....	Michigan	4	690	602	88	12.7				
			74	357	307	50	14.0				
			104	496	477	19	3.8	10.2	0.93	0.42	1.35
Medium	....	Minnesota	3	668	612	56	8.4				
			73	425	365	60	14.1				
			103	401	365	36	9.0	10.5	0.95	0.56	1.51
Medium	2220	Idaho	7	677	605	72	10.6				
			77	365	330	35	9.6				
			107	331	297	34	10.3	10.2	1.02	0.56	1.58
Average for strains omitting alsike								9.0	1.00	0.52	1.35

Strains from Ohio, Tennessee and Oregon											
Medium	2135	Ohio	10	578	505	73	12.6				
			80	381	272	109	28.6				
			110	465	395	70	15.1	18.8	1.00	0.61	1.61
Medium	2138	Tennessee	9	385	342	43	11.2				
			79	339	273	66	19.2				
			109	302	233	69	22.8	17.9	0.77	0.64	1.41
Medium	2148	Oregon	8	550	371	179	32.5				
			78	228	136	92	40.4				
			108	193	139	54	28.0	33.6	0.61	0.56	1.17
Average for strains								23.4	0.79	.60	1.40
Strains from Northern Europe											
Mammoth	54707	Finland	20	455	383	72	....	15.8	1.63	....	1.63
Mammoth	54708	Finland	21	426	339	87	....	20.4	1.13	....	1.13
Medium	54905	Poland	35	641	499	142	22.2				
			100	495	445	50	10.0				
			130	83	63	20	24.1	18.8	0.98		
Medium	2216	Bohemia	12	805	601	204	25.3				
			82	238	160	78	32.8				
			112	397	308	89	22.4	26.8	1.01	0.68	1.69
Medium	2218	No. Germany	14	660	436	224	33.9				
			84	375	279	96	25.6				
			114	324	210	114	35.2	31.6	0.93	0.54	1.47
Medium	2121	Bohemia	11	632	461	171	27.1				
			81	350	196	154	44.0				
			111	413	284	129	31.2	34.1	1.18	0.62	1.80
Average for strains								24.6	1.14	0.61	1.54

TABLE 2.—(continued).

Kind of clover	Number	Source	Plot no.	Counts of clover plants on three square yard areas on the given number of plots of each variety. Total plants	Living plants	Dead plants	Killing %	Average winter-killing %	Yields of hay per acre on a 15% moisture basis First cutting Tons	Second cutting Tons	Total Tons
Strains from Northern Europe and Australia											
Medium	2214	Hamburg	15	792	524	268	33.8				
			85	273	152	121	44.3				
			115	259	126	133	51.4	43.2	0.83	0.60	1.43
Medium	2225	Bohemia	22a	654	370	284	....	43.4	1.18	0.47	1.54
Medium	54889	Holland	18	623	289	334	....	53.6	0.69	0.35	1.04
Medium	2219	Hungary	13	751	341	410	54.6				
			83	290	127	163	56.2				
			113	376	142	234	62.2	57.7	0.83	0.58	1.41
Medium	2256	Australia	17	592	278	314	53.0				
			87	452	203	249	55.1				
			117	369	96	273	74.0	60.7	0.80	0.57	1.37
Average for strains								51.7	0.87	0.51	1.38
Strains from France and Wales											
Medium	54493	France	29	584	106	478	81.8				
			94	234	56	178	76.1				
			124	300	90	210	70.0	76.0			
Medium	2213	France	30	544	127	417	76.7				
			95	175	29	146	83.4				
			125	213	41	172	80.8	80.3			
Medium	54456	France	27	985	172	813	82.5				
			92	244	39	205	84.0				
			122	254	53	201	79.1	81.8			
Medium	2202	France	20	412	49	363	88.1				
			91	248	26	222	89.5				
			121	165	46	119	72.1	83.2			

Medium	2215	France	28	639	86	553	86.5	
			93	194	31	163	84.0	
			123	153	29	124	81.0	83.8
Medium	54467	Wales	16	727	118	609	83.8	
			86	333	67	266	79.9	
			116	298	42	256	85.9	83.2
Average for strains								81.4
Strains from Chile								
Medium	2217	Chile	23	459	48	411	89.5	
			88	295	58	237	80.3	
			118	233	28	205	88.0	85.9
Medium	2203	Chile	25	644	80	564	87.6	
			90	401	43	358	89.3	
			120	298	46	252	84.6	87.2
Medium	2142	Chile	24	505	32	473	93.7	
			89	288	31	257	89.2	
			119	114	10	174	94.6	92.5
Medium	2055	Chile	22	421	33	388	....	92.2
Average for strains								89.5
Strains from Italy								
Medium	54492	Italy	31	998	67	931	93.3	
			96	184	18	166	90.2	
			126	254	21	233	91.7	91.7
Medium	54728	Italy	34	625	14	611	97.8	
			99	281	32	249	88.6	
			129	196	19	177	90.3	92.2
Medium	2212	Italy	33	824	31	793	96.2	
			98	374	34	340	90.9	
			128	253	13	240	94.9	94.0
Medium	54779	Italy	32	716	13	703	98.2	
			97	354	9	341	97.5	
			127	307	12	295	96.1	97.3
Average for strains								93.8

was on a soil of better physical condition and somewhat more productive than that of the adjoining series on which the third and fourth plots of each strain were grown. Two strains from Finland and one each from Bohemia, Holland and Chile were grown only on duplicate plots and therefore occurred only on the soil in the better physical condition. Because of lack of time, no counts were made on the second plot of each strain, but the stands on them checked very closely with those on the first plot of each strain grown on the same series. With a few exceptions, the winterkilling percentages are as consistent as could be expected under the conditions.

The strains are grouped in the table according to the average percent of winter killing. This method of grouping brings together fairly well strains of similar origin.

Considering first the strain native to the clover seed producing sections of North Central and North Intermountain states, the data show a maximum winterkilling percentage of 20.1 on any one plot. The average winterkilling for this group of strains is 9 per cent, not including the data for the alsike. The yields per acre are lower for the mammoth strains than for the alsike or the medium red. The differences in yields of the medium red strains are not great enough to be considered significant.

In the next group, there are included the strains of native seed grown in states farther to the east, south, and west than those of the first group. The average winter killing is higher than for the strains in the first group, but there still remained alive and in a vigorous condition in the plots planted with seed from Ohio and Tennessee, two hundred and thirty-three plants per square yard as a minimum. This is ample to produce a good yield of hay. The strain from Oregon had poorer stands in three of the plots and the plants were not as vigorous as is desirable.

The strains from northern Europe have been divided into two groups according to the percentage of winterkilling, which averages 23.4% in the first and 51.7% in the second group. The stands from the Polish and Australian strains varied considerably on the four plots planted with seed from these sources. Where the number of vigorous plants was much below one hundred fifty to two hundred, the hay was coarse and contained considerable weeds.

The winter killing for the strains from France, including one strain each from Wales, Chile, and Italy averaged 81.4%, 89. 5%, and 93.8%, respectively. While the first plot of the four of the French strains and the strain from Wales had a fair stand, the other three were so poor that no yields were taken. The average number

of vigorous plants per square yard for the Chilean and Italian strains was so small that no cuttings were made. It was difficult to see the clover plants on account of the weeds which had sprung up in the space left vacant by the clover plants which were killed.

SUMMARY

In Minnesota, medium red clover seed produced in the Northern tier of the North Central and the North Intermountain states gave uniformly low percentages of winterkilling and averaged good yields of hay in both the first and second cuttings.

Seed produced in Tennessee and Oregon did not give as uniformly satisfactory results as that produced farther north.

The strains coming from Northern Europe winterkilled to a greater extent than the Northern-grown native strains, but on a very large majority of the plots a sufficient number of vigorous plants remained to give good yields, with few exceptions. The results with the strain from Australia were more variable than the results from the Northern European strains.

Strains of medium red clover seed produced in France, Chile, and Italy winterkilled 81%, 89.5%, and 93.8%, respectively, and no measurable yields of hay were secured.

Seed produced in the northern tier of states of the United States should be given preference in all reseedings made in these states in 1924 and following years. This is important in order that growers may be certain of having good-seed-yielding strains, which will produce seed of the hardy strains needed to maintain good stands in this section in the future.

Until it can be known with reasonable certainty that seed shipped to the United States from north European countries has actually been produced there, such seed cannot be recommended.

Seed produced in France, Chile, and Italy obviously has no place in Minneosta or other states of similar climate. In northern locations where stands obtained from these sources did come through the winter and produce yields, there was a good snow covering for their protection. Snow coverings cannot be relied on to remain during any winter in any of the northern states. Therefore, the fact that these strains did live through one winter can scarcely be interpreted as proof that their use throughout a period of years would be satisfactory.

The conclusion is obvious that a livestock farmer who depends on clover to feed his herd cannot afford to sow anything but native northern-grown seed and can well afford to pay a premium for such seed.

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LITERATURE CITED

1. WEATHER CROPS AND MARKETS. Vol. IV, No. 11, Sept. 15, 1923.
2. WIGGANS, R. G. Home grown and imported clover seed. *In* Jour. Amer. Soc. Agron. 13:332–335. 1921.
3. —— Relative adaptability of home-grown and foreign grown red clover seed. *In* Jour. Amer. Soc. Agron. 15:500–507. 1923.
4. MCGEE, C. R. Hardy alfalfa and clover seed. *In* Mich. Quarterly Bul. 5:16. 1922.
5. PIETERS, A. J. Domestic versus foreign clover seed. *In* Seed World, 15: 13–15. 1923.
6. ARNY, A. C. and STEINMETZ, F. H. Field technique in determining yields of experimental plots by the square yard method. *In* Jour. Amer. Soc. Agron. 11:81–106. 1919.

MODIFICATIONS OF PLANT GROWTH AND ASH CONTENT AS EFFECTED BY ACIDS ADDED TO SOILS[1]

R. H. CARR AND H. G. HAVERCAMP[2]

That there is a distinction between *acid* soils and *toxic* soils has been noted by many soil investigators, but the conditions of acidity which develop unfavorable and toxic, or acid, soils are not well defined or understood. The term *toxic* is usually applied in a broad way to any soil that is unfavorable to plant growth; whereas *acid*, in its chemical meaning, refers to free hydrogen ions, or more generally to the result of this ionic activity in producing compounds of the acids that are harmful to the growth of plants. Thus, aluminum acetate and sulfate are the results of the activity of acids in soils, or acid toxicity, whereas the presence of such compounds as cumarin, or dihyroxystearic acid, etc., cause the soils to be often referred to under the general head of toxic or organic toxicity. The effects of organic

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toxins are not so easily studied as are those connected in some way with acidity, hence acidity to many has come to mean the same as toxicity in soil.

The writers do not believe that acidity by itself, in the concentrations usually found in a soil, is harmful to a plant. This general view seems to be expressed also by McCall (1),[3] and with certain limitations by Truog (2). In previous work by one of the writers (3), it has been found possible to inject 30 cc. of tenth-normal hydrochloric or sulfuric acid or 20 cc. of 1 percent acetic or malic acid into corn plants without any apparent injury. The plants, however, seemed to be unable to stand the same quantities of two-tenths normal acids.

EXPERIMENTAL WORK

Purpose of Experiment

This investigation was planned to test the injurious effects of an organic acid, acetic, as compared with those of an inorganic one, sulfuric, when added in different amounts to a silt or a clay loam soil. In addition to these, two other inorganic acids, silicic and phosphoric, were used, because of their ability to combine with aluminum, iron and possibly manganese and thus make less soluble and less toxic compounds of these elements, even in the presence of the free acids added.

Plan of Investigation

Two series of plants were grown in gallon crocks in a greenhouse, using soils treated with varying amounts of different half-normal acids (the normality was determined by titrating against half-normal sodium hydrate, using phenphthalein as indicator). In the first series Sioux silt loam soil was used and Itosan soybeans were planted in all pots. Each set of two pots had the following amounts of acid added weekly: 5 cc., 10 cc., 15 cc., 20 cc., and 25 cc., respectively. This made forty-five pots in all, of which forty had the four different acid treatments and five were checks. In the other series, Miama clay loam soil was used and buckwheat was grown in all the pots. The acid solutions were added to the edge of the pot, after first having been mixed with the proper amount of water needed to maintain optimum moisture conditions. This acid treatment was continued for ten weeks, thus making a total of 50 cc. for the pots having the least acid added and of 250 cc. for those receiving the highest amount.

Plant Growth Obtained

The green weights of the plants obtained from the soils which had received the different acid treatments are given in Table 1.

[3]Reference by number is to "Literature Cited," p. 283.

TABLE 1.—*Table showing the average green weights at ten weeks of soybeans and buckwheat plants from soils treated with different acids.*

	Sulfuric acid pots		*Silicic acid pots*	
	Soybeans	Buckwheat	Soybeans	Buckwheat
5cc	70.5 gms	18.5 gms	59.0 gms	27.5 gms
10cc	58.5 "	17. "	70.5 "	28. "
15cc	60. "	16. "	74. "	31. "
20cc	50. "	14.5 "	61. "	27.5 "
25cc	51. "	13. "	74. "	27.5 "
Total	290. "	79. "	338.5 "	141.5 "
	Phosphoric acid pots		*Acetic acid pots*	
	Soybeans	Buckwheat	Soybeans	Buckwheat
5cc	49.5 gms	20. gms	54.5 gms	9.5 gms
10cc	53. "	21. "	72.5 "	10. "
15cc	44. "	22.5 "	35.5 "	5. "
20cc	55. "	19. "	25. "	4.5 "
25cc	48. "	18. "	36. "	3.0 "
Total	249.5 "	105.5 "	221.5 "	32.0 "

Average of checks: Soybeans, 53.5 gms.; Buckwheat, 24.0 gms.

It will be noted from the data presented in Table 1 that in both series of plants in the sulphuric and acetic acid treatments the weights of the plants decreased as the amount of acid was increased; while in the silicic and phosphoric acid treatments the weights of the plants either continued about the same or increased as the amount of acid increased. The probable reason for this will be given following the

TABLE 2.—*Table showing percent and partial composition of ash of buckwheat plants grown on soil containing different acids.*

	Amount acid added Percent	Total ash Percent	CaO Percent	MgO Percent	Al_2O_3 Percent	Fe_2O_3 Percent	Mn_3O_4 Percent
			Composition of the Ash				
Sulfuric acid	5cc.	7.45	22.40	2.67	8.73	.301	.43
Series	10cc.	7.81	22.32	7.44	2.77	.333	.45
	15cc.	8.08	19.01	4.75	3.44	.361	.51
	20cc.	9.74	7.15	3.88	3.59	.387	.55
	25cc.	10.89	5.59	3.27	3.91	.390	.54
Totals		43.97	76.47	28.07	*16.38*	*1.772*	*2.48*
Silicic acid	5cc.	7.21	11.19	3.51	.07	.272	.39
Series	10cc.	8.18	12.92	3.70	0.06	.273	.42
	15cc.	8.51	13.61	3.72	0.06	.267	.39
	20cc.	10.99	14.51	4.20	0.04	.270	.39
	25cc.	11.96	14.75	6.65	0.02	.259	.35
Totals		46.85	66.98	21.78	*0.25*	*1.341*	*1.94*
Acetic acid	5cc.	8.82	9.61	2.73	3.75	.300	.39
series	10cc.	8.74	9.04	2.07	3.77	.306	.42
	15cc.	8.43	8.03	1.77	3.99	.327	.47
	20cc.	8.28	7.93	1.54	4.44	.372	.44
	25cc.	8.00	6.00	1.15	4.52	.421	.53
Totals		42.27	30.61	9.26	*20.47*	*1.726*	*2.25*
Phosphoric acid	5cc.	10.32	11.37	3.01	0.86	.257	.35
series	10cc.	9.53	12.45	3.28	0.87	.259	.35
	15cc.	8.58	12.57	3.37	0.85	.263	.35
	20cc.	7.29	12.65	3.44	0.77	.271	.24
	25cc.	7.04	13.55	3.35	0.76	.270	.20
Totals		42.76	62.59	16.45	*4.11*	*1.320*	*1.49*
Checks		8.96	10.07	3.95	0.28	.273	.39

presentation of Tables 2 and 3, where the mineral differences of the plants are shown. It is of interest, however, to note the large amount of acid which may be added to a soil without preventing good plant growth. This result seems to follow when the acid chosen is of such a type as to permit the formation of the relatively insoluble compounds

TABLE 3.—*Table showing percent and partial composition of ash from soybean plants on soils containing different acids.*

	Amount acid added	Total Ash Percent	CaO Percent	MgO Percent	Al_2O_3 Percent	Fe_2O_3 Percent	Mn_3O_4 Percent
Sulfuric acid	5cc.	9.48	8.21	2.76	4.77	.218	.0182
Series.....	10cc.	9.49	7.13	2.00	4.96	.238	.0725
	15cc.	9.65	5.50	1.87	5.05	.378	.102
	20cc.	9.87	3.55	1.59	5.07	.413	.116
	25cc.	14.00	2.01	1.37	5.10	.419	.167
Totals.....		52.49	*26.40*	*9.59*	24.95	1.666	.475
Silicic acid	5cc.	9.07	6.93	2.13	3.69	.215	.069
	10cc.	8.35	7.0	2.16	4.50	.209	.108
	15cc.	8.29	7.05	2.81	4.92	.200	.145
	20cc.	8.01	7.56	2.81	4.93	.195	.174
	25cc.	7.91	8.45	3.12	5.34	.198	.192
Totals.....		41.63	*36.99*	*13.03*	23.38	1.017	.688
Acetic acid	5cc.	7.27	6.94	1.47	5.50	.215	.132
Series.....	10cc.	8.54	4.00	1.51	5.63	.237	.138
	15cc.	8.61	2.24	1.41	6.22	.357	.143
	20cc.	9.11	2.31	.96	6.48	.477	.154
	25cc.	9.52	1.99	.72	8.31	.503	.163
Totals.....		43.05	*17.48*	*6.07*	*32.14*	1.789	.730
Phosphoric acid	5cc.	8.33	10.0	2.69	2.85	.206	.186
Series.....	10cc.	8.66	6.86	2.48	3.59	.247	.154
	15cc.	8.72	5.81	2.42	3.72	.301	.117
	20cc.	10.94	4.76	2.03	3.78	.299	.082
	25cc.	12.18	3.63	1.78	4.26	.302	.075
Totals.....		48.83	*31.06*	*11.40*	*18.20*	1.355	.614
Checks......		9.42	6.89	2.90	4.02	.207	.078

with iron, aluminum, etc., which are harmless to the growing plant. The acetic and sulfuric acids both formed easily soluble salts of these elements, whereas silicic and phosphoric acids produced much less available and less toxic compounds of these metals.

Ash Composition of Plants Grown

The plants grown on both series of soils were saved for analyses of the ash. This analysis was carried out according to the official methods for ash analysis. The data for the two series of plants are given in Tables 2 and 3.

It will be noted from the data presented in Tables 2 and 3 that there are many marked differences in the ash content of plants grown in soils containing increasing amounts of acid.

The calcium content of the buckwheat series is much higher than that of soybean. Also, it will be noted that both the calcium and magnesian decrease rapidly as the sulfuric or acetic acid increase,

whereas the opposite seems to be true with the silicic and phosphoric acid treated plants in all except the soybean plants in the phosphoric acid treatment. No definite reason is apparent for this striking exception. It will be observed from Table 2 that both the sulfuric and acetic acid treated plants contained considerable aluminum and iron and these increased in amount as acidity increased, but only small percentages were found in the silicic and phosphoric acid treated pots. The same was true in the soybean pots except the differences were much less marked. This ability of the soybean plant to withstand the invasion of aluminum compounds may be a reason for its fair growth on soils which are toxic to many other plants.

It will be noted that there is more iron, as well as manganese, in the acetic and sulfuric acid series in the buckwheat plants than in those treated with the other two acids. Both of these facts furnish additional reasons for the poor growth of plants from soils treated with these acids.

The same conditions regarding iron were found in the soybean plant as were observed in the buckwheat.

Thus it is evident that the poor growth of these plants on the sulfuric and acetic acid treated soils, as compared with that on the soils treated with other acids used, must have been due in large part to the toxic elements present in the former which were there in much smaller amounts in the latter.

Acidity of the Treated Soil

After the plants had been harvested, samples of the soil were taken from all the pots and lime-requirement determinations were made on them by the potassium thiocyanate method. The data for certain of the soils treated in different ways are given in Table 4 below.

The phosphoric and silicic acid treatments had precipitated to a

TABLE 4.—*Lime requirements of several soils as determined by the potassium thiocyanate method.*

	Amount acid added	Cc. of N/10 KOH used	Pounds of calcium carbonate needed per acre to neutralize acidity
Sulfuric acid series....	5cc.	11.5	2300
	15cc.	12.5	2500
	25cc.	19.5	3900
	5cc.	14.5	2900
Acetic acid series.....	15cc.	16.5	3300
	25cc.	19.5	3900
	5cc.	7.5	1500
Silicic acid series......	15cc.	3.0	600
	25cc.	0.0	0
	5cc.	6.0	1200
Phosphoric acid series.	15cc.	7.0	1400
Checks	25cc.	1.0	200
(Average)..........		3.5	700

large extent the dissolved toxic elements and hence but little limestone was needed in soils treated with these acids. Thus in both these cases there is what may seem to be the strange anomaly of adding acids to correct the toxic conditions in acid soils.

SUMMARY

A comparison has ben made of the effect upon the growth of soybean and buckwheat plants of adding an organic (acetic) and an inorganic (sulfuric) acid to a silt and a clay-loam scil. It has been found that both acids seriously interfere with plant growth, but that acetic was more deleterious than sulfuric acid. This is believed to be due to the effect of acetic acid in supplying more toxic aluminum and iron, etc., to the plant and in decreasing calcium and magnesium to a greater extent than was done by the sulfuric acid.

In addition two other series of acids (phosphoric and silicic) were used, because they make compounds with aluminum and iron which seem to be harmless to the growing plant, regardless of the fact that the root is surrounded by a soil which is highly acid. The good growth of both kinds of plants obtained, even when rather large amounts of these latter acids were added, indicates that relatively insoluble compounds of aluminum and iron, etc., were formed and that the acid by itself did no harm.

LITERATURE CITED

1. McCall, A. G. The influence of acidity itself on plant growth without regard to other factors. *In* Jour. Am. Soc. Agron. 15:290-297. 1923.
2. Truog, Emil. Soil acidity in relation to the growth of plants. *In* Jour. Am. Soc. Agron. 5:169-195. 1918.
3. Hoffer, G. N. and Carr, R. H. Accumulation of aluminum and iron compounds in corn plants and its probable relation to root rots. *In* Jour. Agric. Res. 23:801-823. 1923.

THE INHERITANCE OF SMUT RESISTANCE IN CROSSES OF CERTAIN VARIETIES OF OATS[1]

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INTRODUCTION

The enormous annual loss of farm crops resulting from the attack of various diseases is common knowledge. An investigation which may directly or indirectly lead to a knowledge of how to reduce

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some form of such loss is undoubtedly justified. Since Biffen's (2)[3] investigations, indicating the possibility of isolating resistant families from crosses of varieties differing in susceptibility, a marked impetus has been given to breeding as a means of disease control. Very definite results have been achieved during the past decade in relation to the genetics of resistance, the isolation of resistant families from crosses, and the isolation of resistant varieties thru testing.

The present investigation has for its purpose a study of the inheritance of resistance in a number of crosses of varieties of oats to the organism *Ustilago avenae*, which causes the disease known as "loose smut." The attack of *Ustilago avenae* is confined to the genus *Avena*. Natural inoculation of the host occurs when the grain is mature and standing. Wind conveys the spores from the diseased to the healthy panicles. Infection occurs at the time of germination of the seed. The conditions that favor the germination of seed are also in general conducive to the germination of the spores. Having gained admittance to the seedling, the parasite is carried along in the growing region of the host. A new crop of spores replaces the seed that should have been borne in the panicle. Although the disease can be rather effectively controlled by the use of fungicides, information relative to the genetical response of the host to an exposure of this parasite is interesting and valuable.

The present investigation has been underway for the past three years and is being continued. This report, although only preliminary, will contain a portion of the data obtained and will indicate the trend which the investigation is taking at present. Results of a few recent investigations somewhat related to the work herein discussed will be presented.

Aamodt (1) found that, when a single biologic form of rust was concerned, segregation for resistance in the progeny of a cross between Kanred and Marquis wheats approximated a ratio of three resistant to one susceptible plant.

Garber (4) reports crosses of two pure lines of oats, Minota and Victory, which are susceptible, with White Russian, which is relatively resistant to stem rust. A study of the F_2 and F_3 generations of these crosses indicated that resistance was dominant, and that a single factor pair was responsible for the segregation observed.

Gaines (3), in referring to bunt resistance in the wheat crosses Turkey x Hybrid 128 and Fortyfold x Turkey, states:

"The picture of the inheritance of these two crosses is one in which sus-

[3]Reference by number is to "Literature Cited," p. 291.

ceptibility is dominant, with the susceptible segregates fluctuating around the mean of the susceptible parent in each case."

Again, (p. 466) he states:

"It is difficult to place these phenomena of inheritance on a factorial basis on account of the seasonal fluctuations and the quantitative and comparative nature of the material. It is quite evident, nevertheless, that Turkey has several times as much resistance to bunt as Fortyfold."

Waldron (7) reports his findings in relation to the susceptibility of hybrid wheats to stem rust. In all tests he found the F_1 hybrids heavily attacked by stem rust. The behavior of subsequent generations in relation to the rust he attributed to multiple factors, suggesting that two factors substantiate the data he presented more nearly than any other number.

Wakabayashi (6) reports an investigation of the inheritance of smut resistance in oats. He used covered smut (*Ustilago levis*). Crossing a resistant with a susceptible variety, he obtained no smut in the F_1 and F_2 generations. In the F_3 twelve rows contained smutted plants while ninety-five rows contained no smutted plants. He thought that perhaps immunity was due to three independent dominant factors.

Methods of Investigation

The parent and first generation plants of the crosses herein discussed were grown in the greenhouse. The second generation of one group of crosses, and the third, fourth and fifth generations of other crosses were grown in the field. A uniform method of planting and inoculating seed was followed.

For the purpose of inoculating the seed an envelope containing a few ounces of spores was provided, into which the respective samples of seed were placed and thoroughly shaken. The excess spores were strained out through a tea strainer.

Preliminary experiments relative to the effect of soaking the seed previous to inoculation indicated that soaking was without noticeable effect. Check rows of non-inoculated seed were grown in a number of cases, and in no case did any of them contain smutted plants.

EXPERIMENTAL DATA

Twelve varieties of oats including Aurora, Burt, Black Mesdag, Black Tartarian, Cornellian, Fulghum, Gold Rain, Lincoln, Swedish Select, Turkish Rustproof, White Tartarian and a strain of *Avena sterilis* were used as parental material. From these varieties thirty-one crosses were made, which are being studied in relation to resistance. Data on the first and second generations of these crosses have been obtained. Seventy families from the second generation of two

other crosses were obtained from the Department of Plant Breeding and have been studied for resistance through the third, fourth and fifth generations.

As the third generation of the thirty-one crosses first mentioned is to be grown during the coming season, this report will be limited to three characteristic crosses, and the seventy families mentioned last.

An analysis of the data from the second generation of the crosses, considered in relation to the varietal resistance manifested by the parents, indicates that the crosses naturally fall in definite groups. Segregation in the various groups has been interpreted on the basis of one, two, and three independent factor pairs.

A typical cross from each of these groups and a statement relative to the varietal resistance exhibited by the parents concerned in each cross will now be presented.

Cross No. 5 (Table 1) is presented as characteristic of the seven crosses included in group 1. Segregation in this group is interpreted on the basis of three independent factor pairs.

The second group of crosses is interpreted on the basis of a difference of two independent factor pairs in the parents. Five crosses are included in this group, and cross No. 21 is presented as typical of this group.

The third group contains four crosses which segregate as though the parents differed by only one factor pair. Cross No. 37 is presented as characteristic of this group. The remaining crosses, which fall into two groups, will be reserved for later presentation.

Before entering upon the discussion of Table 1, it should be stated that parental variety tests were conducted for two years with the varieties concerned. According to these tests, which coincide rather closely with data for some of these varieties presented by Reed (5), they would be classified for resistance to smut as follows: Black Mesdag, Burt and Fulghum are resistant; Gold Rain intermediate; Swedish Select and Turkish Rustproof are quite highly susceptible. It should be emphasized that, on account of the methods of inoculating, not all susceptible plants in a variety or progeny will be found smutted. Likewise, resistance does not necessarily indicate immunity.

As a suggestion, and without at present attempting to elaborate such suggestion, the following are offered as possible combinations to account for the three types of segregation noted

Pedigree	5	SS	s′s′	s″s″	x	ss	S′S′	S″S″
"	21	ss	s′s′		x	SS	S′S′	
"	37		ss		x	SS		

In each case the factor S is responsible for resistance.

TABLE 1.—*Segregation in the second generation of various crosses into resistant and susceptible classes.*

Parents	Series number	Observed Ratio Non-smutted	Observed Ratio Smutted	Calculated Ratio Basis of 64, 16 & 4 Non-smutted	Calculated Ratio Basis of 64, 16 & 4 Smutted	Deviation	P. E.	Dev./P.E.
Fulghum x Black Mesdag	5a 1	50	1					
	5a 2	44	1					
	5a 3	62	0					
Total	5a	156	2	155.53	2.47	.47	1.05	.44
Swedish Select x Burt	21a 1	86	6					
	21a 2	58	4					
Total	21a	144	10	144.37	9.63	.37	2.03	.18
Turkish Rustproof x Gold Rain	37a 1	38	9	35.25	11.75	2.75	2.00	1.37
	37a 2	42	10	39.00	13.00	3.00	2.11	1.42
	37a 3	36	9	33.75	11.25	2.25	1.96	1.14
	37a 4	38	13	38.25	12.75	.25	2.09	.11
	37a 5	42	8	37.50	12.50	4.50	2.07	2.17
	37a 6	63	7	52.50	17.50	10.50	2.44	4.30
Total	37a	259	56	236.24	78.76	22.76	5.18	4.38

The three crosses presented, judging from both the family segregations and the total segregations, as indicated in the last column, approach very closely to what would be expected according to the basis on which they are interpreted. The deviation observed in the total of progeny 37 is due to the fact that for each separate family there are too few smutted plants and this results in a gradual accumulation so that the total smutted plants observed are much less than the expected number.

It is recognized that too much dependence should not be placed on the above segregations, until a third generation of these crosses is grown. The data obtained approach so closely what is expected, when judged from the standpoint of parental grouping for smut resistance, that it was thought worth while to present the results before waiting for the third generation.

If the interpretation of the F_2 segregation, as here presented, is sound, an approximation of the following results may be expected in the third generation from the various groups. Where segregation occurs on the basis of three factor pairs, the sixty-three resistant F_2 genotypes may be expected to behave as follows: Thirty-seven will breed true for resistance, twelve progenies will segregate into a 15:1 ratio, six progenies will segregate into a 3:1 ratio. The eight remaining progenies will repeat the behavior of the F_2 by segregating into a 63:1 ratio again. Where segregation occurs on the basis of two factor pairs, about seven out of the fifteen resistant F_2 genotypes will breed true for resistance; four will segregate into a 15:1 ratio, and four will segregate into a 3:1 ratio. Where segregation occurs on the basis of one factor pair, one of the three resistant F_2 genotypes will breed true, and two of them will segregate into a ratio of 3 resistant to 1 susceptible plant.

A brief statement may now be given of the behavior of the seventy F_2 families obtained from the Department of Plant Breeding which were tested thru the F_3, F_4, and F_5 generations for resistance. These families are from the crosses Early Ripe x Black Mesdag, and Sixty Day x Black Mesdag.

Black Mesdag is shown to be a highly resistant variety by Reed (5), and data obtained by the writer indicate the same resistance. Early Ripe and Sixty Day have not been included in variety tests by the writer. Reed reports the results of a strain of Early Ripe, which he says resembles Burt. From his data, this strain may be classified as intermediate. His data indicate that Sixty Day is susceptible. Hence, the indications are that susceptible varieties were crossed with a resistant variety, producing the seventy families

Fig. 1 shows a highly susceptible F_5 family which has been breeding true to that characteristic since isolated from the F_2; about seventy-five percent of the plants in this family were infected.

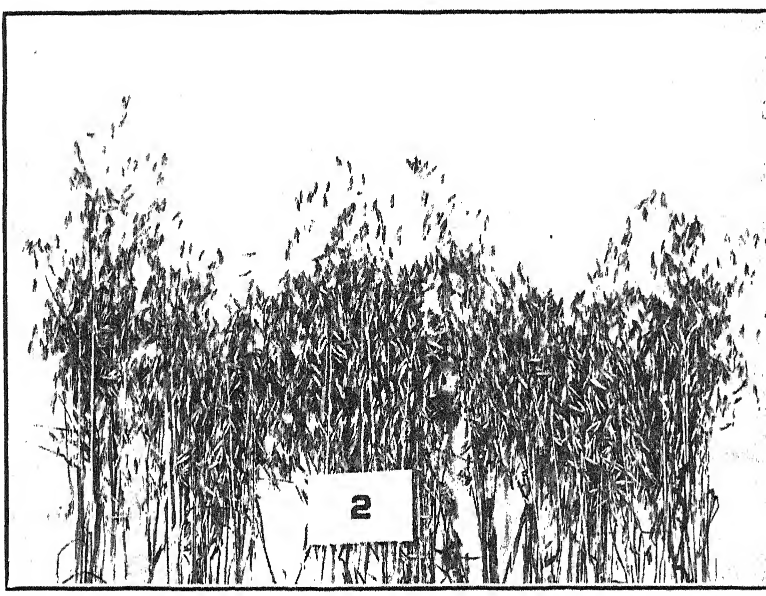

Fig. 2 shows a resistant F_5 family that was grown beside the family shown in figure 1. It breeds true to resistance.

Fig. 3 shows a highly susceptible F_4 as it grew in the field. This illustration is to be compared with No. 4.

Fig. 4 shows a highly resistant F_4 family from the same cross and similarly treated to the preceding family. They grew adjoining each other and were planted and treated similarly. Their differences may, therefore, be considered to be genetical.

under discussion. In order to pursue the investigation in regard to these families, arbitrary standards of classification were established, as there seemed to be no definite ratios obtainable in the third generation. Accordingly all rows that contained no smutted plants were classified as resistant, all rows containing smut up to about twenty percent were classed as intermediate, and all rows containing more than twenty percent of smut were considered susceptible.

Not all of the data from these families will be presented, but families representing each of the three classes are included in Table 2.

TABLE 2.—*Classification of some families from the third generation of the cross Sixty Day x Black Mesdag according to the amount of smut present and their behavior in the fourth generation.*

Pedigree No.	Amount of smut in F_3	Susceptible plants in F_4	Resistant plants in F_4
505a1–149	None	0	108
–1	"	0	61
–179	"	0	117
–183	"	0	112
–184	"	1	107
–140	Medium	6	90
–151	"	4	77
–160	"	0	103
–204	"	3	80
–143	Extreme	34	42
–150	"	22	65
–162	"	29	77
–182	"	40	49
–149	"	20	78

The families included in Table 2 have been selected as characteristic of the classes from which they have been assembled. A study of the distribution of the entire seventy families rather strongly indicates that there was a difference of one factor pair in the parents concerned. If the parents did differ by but a single pair of factors, about one-fourth of the families would be expected to be found in each of the extreme classes, and about one-half to be found in the intermediate class. A total of twenty-two families were found in the resistant class, thirty-two families in the intermediate class and sixteen in the susceptible class. While there are some deviations from the 1:2:1 ratio the deviations are not extremely wide for seventy observations. The twenty-two families in the resistant class subsequently tended to breed true to that characteristic. Likewise, the susceptible families bred true, and the intermediate families segregated into resistant, intermediate and susceptible types.

If the classification was made somewhat accurately in the third generation, it should be possible to select from the fourth generation families which would breed true for resistance, families which would segregate, and families which would breed true for susceptibility in the fifth generation. With such expectations in mind a number of

families were selected from the fourth generation as follows: Twelve families that were classified as being susceptible in the third and fourth generations; one family classified as segregating and seven families resistant in the third and fourth generations. These twenty families were grown in the fifth generation. The results obtained are presented in Table 3.

TABLE 3.—*Results of selecting for resistance and susceptibility to loose smut thru the F_3, F_4, and F_5 generations.*

Pedigree	Percentage of smut in F_3	Percentage of smut in F_4	Number of plants in F_5 Smutted	Number of plants in F_5 Non-smutted	Percentage of smut in F_5
505a1-143-2	31.25	59.09	144	70	67.29
-3	"	68.42	152	102	59.84
-4	"	33.33	68	132	34.00
2-1	35.29	47.05	75	61	55.14
-2	"	15.78	54	130	29.34
-3	"	0.00	117	85	57.92
-4	"	4.76	78	94	45.34
162-2	40.00	47.36	116	101	53.41
-3	"	19.04	158	90	63.71
-4	"	5.26	93	130	41.21
182-1	55.55	33.33	185	71	72.26
-3	"	31.81	135	67	66.83
535a1-228-5	17.64	.00	3	144	2.04
218-3	None	None	None	144	....
228-4	"	"	"	111	....
6-5	"	"	"	71	....
505a1-179-1	"	"	"	165	....
-2	"	"	"	157	....
183-2	"	"	"	85	....
-3	"	"	"	85	....

It is quite obvious from the data shown in Table 3 that families have been isolated from the second generation which have since been breeding true to susceptibility, intermediacy, and resistance, respectively. As may be seen, the tendency among the susceptible families was to maintain or even increase in susceptibility. In fact, eleven out of the twelve families selected were more heavily infected in F_5 than in F_3. Quite a number of the families were more heavily infected in F_4 than in F_3. Four of the families progressively increased in susceptibility thruout the F_4 and F_5.

The family (535a1-228-5) selected for intermediacy in the F_3 may be said to be continuing true to that type. No smut was observed in this family in the F_4 but a small amount, 2.04 percent, appeared in F_5. This slight amount of smut is sharply contrasted with the high percentage in the susceptible families and the lack of smut in F_5 of the resistant families.

In discussing the seven resistant families at the bottom of the table it may be mentioned that they were inoculated precisely as were the susceptible families and with spores of equal viability and that the families grew side by side in a rather compact space. Hence,

the marked differences between the resistant and susceptible families can with fairness be attributed to inheritance.

It is evident then that families have been isolated, from the second generation of crosses of parents differing in susceptibility, which are highly resistant to the attack of smut, and that these families transmit this characteristic to their progeny.

SUMMARY

The data presented indicate that some varieties of oats contain one factor pair for resistance to loose smut, that other varieties contain two independent factor pairs, while in other varieties three factor pairs may be concerned with resistance.

Selection within seventy families from two crosses indicated that resistant families can be isolated in the second generation which breed true to that characteristic thru the F_3, F_4 and F_5 generations. Likewise, highly susceptible families can be isolated which breed true. Such results show the possibility of obtaining desirable types of smut resistant oats from crosses between resistant and susceptible varieties.

The accompanying illustrations (Figures 1, 2, 3 and 4) are presented to indicate the response to smut exposure exhibited by two resistant and two susceptible families.

LITERATURE CITED

1. Aamodt, Olaf S. The inheritance of growth habit and resistance to stem rust in a cross between two varieties of common wheat. *In* Jour. Agr. Res. 24:457–469. 1923.
2. Biffen, R. H. Studies in the inheritance of disease resistance. *In* Jour. Agr. Sci. 2:109–128. 1907.
3. Gaines, E. F. Genetics of bunt resistance in wheat. *In* Jour. Agr. Res. 23:445–480. 1923.
4. Garber, R. J. Inheritance and yield with particular reference to rust resistance and panicle type in oats. Minn. Agr. Exp. Sta. Tech. Bul. 7. 1922.
5. Reed, G. M. Varietal resistance and susceptibility of oats to powdery mildew, crown rust, and smuts. Mo. Agr. Exp. Sta. Res. Bul. 37. 1920.
6. Wakabayashi, S. A study of hybrid oats, *Avena sterilis X Avena orientalis*. *In* Jour. Amer. Soc. Agron. 13:259–266. 1921.
7. Waldron, L. R. Inheritance of rust resistance in a family derived from a cross between durum and common wheat. N. D. Agr. Exp. Sta. Bul. 147. 1921.

THE USE OF CONCENTRATED FERTILIZER AND OF SPECIAL CHEMICALS FOR SOIL TREATMENT[1]

MILTON WHITNEY[2]

For many years the scientists of the world have recognized the need of larger supplies of nitrogen compounds suitable for use in connection with available supplies of phosphoric acid and potash to maintain and increase the yields of wheat and other crops for the increasing population. Nitrate of soda from the Chilean fields and very small deposits of potassium nitrate are the only direct natural supplies of nitrogen in a form available for fertilizers at the present time. The other available forms are by-products—ammonium sulfate from the coke and gas furnaces, cottonseed meal from the cotton plant grown for fiber, animal tankage and dried blood from animals slaughtered for food, fish scrap from non-edible fish and parts of fish, with smaller amounts of garbage tankage and materials from a few other sources.

The production of ammonium sulfate has about reached the high point with the present utilization of coal. Suggestions have been made for substituting coke for coal for industrial and domestic use and there is a possibility, if this should be accomplished, that the supply of ammonium sulfate will be materially increased. All of the by-products carrying organic nitrogen are being used more and more for feeding purposes and the supply available for fertilizers is being rapidly depleted. In any event, the supply of such material for fertilizer purposes cannot be increased beyond the capacity of the country to absorb the main products from which these by-products are derived.

On the other hand, the recognition of the importance of fertilizers in maintaining the productive capacity of our soils and in increasing the yield per acre of crops, as well as the demand for fertilizers, is rapidly increasing. With the wider distribution in the use of fertilizer materials, the cost of transportation is increasing and the burden on the railroads for car space is becoming an important consideration. Therefore, the bulk of the enormous fertilizer tonnage enters as an important item of cost.

For example, a low grade fertilizer formula, such as 2-8-2, made up at present by use of low grade material, could be duplicated by use of only 17 per cent of concentrated fertilizer salts with 83 per cent of useless material; that is to say, instead of a farmer paying the freight

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[2]Chief of the Bureau.

and handling charges on 2,000 pounds of material, he could obtain the same mineral constituents in 340 pounds of mixed mineral salts. He would then have the option of applying this concentrated material with extra care or, if he wanted to dilute it to the concentration he was accustomed to use, he could mix it with 1660 pounds of sand, loam, peat, or any such material, or with water (if he practiced intensive methods of cultivation); or he could have the fertilizer manufacturer mix these 1660 pounds and pay the freight on it, which would be a very uneconomical choice for him to make.

With the commercial production of nitrogen fixed in available forms from the atmosphere practically accomplished, together with the pyrolytic production of phosphoric acid, the possibility has been advanced of making concentrated fertilizers of commercially pure salts; to put the fertilizer industry on a chemical basis where the production of fertilizer material can be controlled and expanded at will without dependence upon organic waste and by-products as at present.

With these possibilities of producing concentrated materials, such as ammonium nitrate, ammonium phosphate, potassium nitrate and potassium phosphate, and their obvious advantages looming up, the question has arisen from many sources as to whether it would not be a mistake to give up materials in present use and whether the pure salts which it is proposed to use would have as important effects as the impure materials now being used.

Attention is called to the belief in the southern states that kainit gives better results than the high grade muriate of potash. Fear is expressed that if an ammonium or potassium phosphate salt be used the elimination of gypsum in the present form of acid phosphate might diminish returns, as sulfur has been found to be very beneficial to soils in certain localities, notably as indicated by the experiments which have been carried on in Oregon. Under the present practice, the farmer who purchases acid phosphate gets 16 percent of phosphoric acid and about 9 percent of sulfur, as a ton of acid phosphate contains approximately 1,000 pounds of gypsum. Zusuki, at the University of Tokyo, has found that gypsum is beneficial on soils with an alkaline reaction or when used with salts like sodium nitrate which tend to leave the soil alkaline, but that it is a deterrent when used on acid soils or in connection with acid phosphate. Common salt, an impurity in many of our fertilizer materials, would be eliminated from the concentrated fertilizers, although common salt has been used with beneficial results, notably in some of the southern states. Likewise, the elimination of other impurities found in some of our present materials is thought to be unwise by those who

are disposed to criticise the concentrated fertilizer movement. A little mature consideration of the facts that have led up to present fertilizer practice will convince one that such criticisms are wholly unjustified.

Animal waste products, including manure, bones and scraps of meat, and ashes, soot, fish, leguminous crops, lime and marl, have been advocated for use on soils from the earliest historic times. Up to the close of the eighteenth century, the composition of the soil and of the plant was wholly unknown, because only a start had been made in determining the chemical elements and methods of analysis. Potash, for example, was not discovered until 1808. As these different chemical elements were discovered and methods of analysis worked out, attention was directed to the composition of air and water, of carbon dioxide and the function it performed in supplying carbon to the growing plant. Then the composition of the ash of plants was studied and the question as to whether the mineral elements found in the ash of plants were essential or not gave rise to a bitter controversy.

As late as 1838, which is only 85 years ago and within the lifetime of men now living, the Göttingen Academy offered a prize for the satisfactory solution of the then vexed question as to whether the mineral ingredients of the plant ash were essential to vegetation. The matter was finally settled in substantially the following way: It was found that plants could be made to grow successfully in well-water frequently renewed. The composition of well-waters was then determined and culture solutions were prepared with pure chemicals, such as sodium nitrate; ammonium sulfate, chloride or nitrate; calcium nitrate; magnesium sulfate or chloride; sodium, ammonium or potassium phosphate; potassium chloride, nitrate, sulfate or carbonate; and a trace of iron. In culture solutions of these salts in distilled water and in appropriate dilutions plants were grown equal to those obtained in field or garden soils. Then began a series of elimination tests with water cultures and with sand cultures and it was found that of the mineral elements potassium, calcium and magnesium, phosphorus in the form of phosphates, nitrogen in the form of nitrate, and sulfur in the form of sulfates were absolutely necessary for the life of agricultural plants. It was found in such careful experiments as could be made at that time that sodium, silicon and chlorine were unessential and that iron was needed in very small quantities. Investigators even considered the case of elements found in very minute traces in the plant such as copper, boron and iodine, with negative results. After transferring the work to field plots, it was found that nitrogen in certain forms, phosphoric acid

and potash were the essential elements necessary to be supplied as fertilizers, with occasional applications of lime and magnesia.

The important thing to be observed here is that the basis of present fertilizer practice was obtained through the use of pure salts, which since then, because of necessity, have been supplied in more or less impure form.

Nitrogen, phosphorus and potassium are the three elements that are most universally needed as mineral plant foods, taking the soil by and large and without specific knowledge to the contrary.

The definition of the term "plant food" is a subject of controversy at the present time. Nitrogen and sulfur enter in as constituent parts of certain proteins that form a part of the living plant. Phosphorus enters into a limited number of living constituents of the plant; but it seems to have other important catalytic actions. Potassium and calcium do not appear to form a constituent part of the living organic matter of a plant; but are very essential in their catalytic action in the conversion of starch into cellulose, which does not occur in the absence of calcium, and of the conversion of starch into sugar or of the reverse action, which do not take place in the absence of potassium. Whether such catalytic agents, the purpose of which is to help in the transformation of material, but which do not form a constituent part of the material, can be properly designated as "plant food" is difficult to determine, but in the present paper they will be given the common usage in referring to them as mineral plant foods. It must be remembered that the mineral elements have as important a part to play in the life and activities of the soil organisms as they have in the life processes of the higher order of plants, but for the purpose of the present paper this action of fertilizers on the organisms of the soil itself is passed over.

In other papers attention has ben called to the rather close analogy between the soil type, considered as a dynamic entity, and the human body and this analogy may be used at the present time to throw an important light upon fertilizer practice.

Man has a comparatively short list of essential food materials. Until recently the food value has been calculated from the content of proteins, carbohydrates and fats, with consideration given to the amount of mineral salts remaining in the ash. Recently, endeavors have been made to separate the different kinds of proteins, carbohydrates, and fats, recognizing that they have different feeding values; and at present great emphasis is being laid on the vitamines, the composition or constitution of which is not yet understood. The

bulk of the three major food constituents of man consisting of proteins, carbohydrates and fats are contained in

Meat of domestic cattle, sheep, hogs and poultry, and such products as milk, butter, cheese and eggs,

Cereals, such as wheat and rice,

Vegetables, such as potatoes and cabbage,

Fruits, such as apples, pears, peaches and oranges.[3]

Man needs, therefore, chiefly three food constituents contained in a relatively short list of food materials. In the U. S. Pharmacopoeia, the National Formulary and the U. S. Dispensatory, there are upwards of 4,000 chemicals, drugs and mixtures described for use in external and internal applcations to keep man in a normal state of health and efficiency. There are many other drugs in more or less common use not listed in these three volumes; there are treatments with antitoxins and vaccines that are not included, so that in all there must be many thousands of drugs and preparations that are being used to maintain human efficiency.

The principal purposes for which drugs are administered may be conveniently classified into four groups as follows: (1) To supply a deficiency in the diet of one or more essential food constituents such as iodine when taken as potassium iodine or vitamin A in the form of cod liver oil. (2) To act as a stimulant or depressant. (3) To prevent infection through antiseptic action, and (4) To correct an unhealthy or morbid tendency by use of alteratives.

The addition of any of these groups of drugs to marketed food products as a general procedure on the assumption that they might be beneficial to some people under some conditions has never been advised. On the contrary, very stringent laws have been passed to prevent adulteration and to keep food products as clean, sound and healthful as possible. Other laws or parts of laws provide for purity

[3]The U. S. Bureau of Labor Statistics lists the following as the standard articles of our national diet in estimating the cost of living.

Sirloin steak	Nut margarine	Potatoes
Round steak	Cheese	Onions
Rib roast	Lard	Cabbage
Chuck roast	Vegetable lard substitute	Beans, baked
Plate beef	Eggs	Corn, canned
Pork chops	Bread	Peas, canned
Bacon	Flour	Tomatoes, canned
Ham	Corn meal	Sugar, granulated
Lamb	Rolled oats	Tea
Hens	Corn flakes	Coffee
Salmon (canned)	Wheat cereal	Prunes
Milk, fresh	Macaroni	Raisins
Milk (evaporated)	Rice	Bananas
Butter	Beans, navy	Oranges
Oleomargarine		

and certain strengths of drugs and while many people take stimulants and various condiments with their food, drugs on the whole are supposed to be administered only under competent direction and supervision.

The higher order of plants normally obtain their mineral requirements from that highly complex material which is called the soil. It has been found, however, from innumerable experiments that have been made all over the world, that where they are given artificial supplies of nitrogen, phosphoric acid, and potash in suitable combinations, their development and growth is generally stimulated and the yield, particularly of annual crops, is correspondingly increased. These three elements have, therefore, come to be considered the important elements of mineral plant foods which are supplied to the soil in commercial fertilizers. The common forms and almost the only forms in which these elements can be safely applied to the soil in mineral form are: nitrogen, in the form of sodium nitrate, ammonium sulfate, chloride, carbonate, nitrate and phosphate, and calcium nitrate; phosphorus combined with calcium, sodium, ammonium and potassium; and potassium as phosphate, chloride, nitrate, carbonate and sulfate.

In addition to this short list of chemicals, carrying what is recognized as the three essential plant food elements in an available and usable form, there is presented below a table of 296 substances, 134 inorganic and 162 organic, which have been tested on soils or in water culture solutions and which may be considered as bearing the same relation to the recognized fertilizing elements as the substances mentioned above as listed in the U. S. Pharmacopoeia bear to our standard food materials. They may be used (1) to supply a deficiency in the soil of some essential plant food constituent such as magnesium, sulfur or manganese; (2) to act as plant stimulants or depressants; (3) to serve as antiseptics in destroying harmful soil organisms; and (4) to correct an unhealthy tendency in the soil, such as the development of an acid condition which may be corrected by use of lime.

Acetamide	Ammonium thiocyanate	Arsenious acid
Acetic acid	Amygdaline	Arsenious oxide
Alanine	Amyl alcohol	Asparagine
Allantoin	Aniline (sulfate)	Aspartic acid
Alloxan	Antimony	Aspartic acid (Na salt)
Allyl alcohol	Antipyrine	Atropine (sulfate)
Aluminum	Arbutin	Balsam
Aluminum chloride	Arginine (carbonate)	Barbituric acid
Aluminum sulfate	Arsenic	Barium carbonate
Ammonium alum	Arsenic acid	Barium chloride
Ammonium sulfite	Arsenic oxide	Barium nitrate

Barium sulfate
Benzine
Benzidine
Benzol
Benzylamine (hydrochloride)
Beryllium nitrate
Betaine
Betaine (hydrochloride)
Bismuth
Bismuth phosphate
Biuret
Borax
Boric acid
Borneol
Boron
Butyl alcohol
Butyl alcohol (iso)
Butyl alcohol (tertiary)
Butryic amides
Cadmium
Casesium chloride
Caffeine
Caffeine (hydrochloride)
Calcium acetate
Calcium arsenate
Calcium carbonate
Calcium chloride
Calcium fluoride
Calcium fluorosilicate
Calcium formate
Calcium hydroxide
Calcium sulfate
Calcium sulfite
Camphor
Carbamic acid (methyl salt)
Carbon
Carbon dioxide
Carbon disulphide
Carbon tetrachloride
Cerium sulfate
Chinin
Chloroform
Choline
Choral hydrate
Chromic acid
Chromic alum
Chromium
Chromium oxide
Cinnamic acid
Cinnamic acid (Na salt)
Cobalt
Cobalt chloride
Cobalt sulfate
Cocaine (hydrochloride)
Colophony
Copper
Copper-aceto-arsenite
Copper arsenate
Copper carbonate, basic
Copper nitrate
Copper sulfate
Creatine
Creatinine
Cumarin
Cuprous sulfide
Cyanuric acid
Daphnetin
Dicyandiamide
Didymium nitrate
Dihydroxystearic acid
Diphenylamine (hydrochloride)
Escalin
Ether
Ethyl alcohol
Ferric chloride
Ferric nitrate
Ferric phosphate
Ferrous sulfate
Ferrous sulfide
Formamide
Fumaric acid (Na salt)
Gluconic acid
Gluconic acid (Ca salt)
Glutamine
Glutaminic acid
Glycerol
Glycocoll
Glycocollamide (hydrochloride)
Gold
Gold chloride
Guanidine (carbonate)
Guandine (hydrochloride)
Guanine
Hexamethylenetetramine
Hippuric acid
Hippuric acid (Na salt)
Histidine (carbonate)
Hydrocyanic acid
Hydrogen peroxide
Hydroquinone
Hypoxanthine
Indium
Iodine
Iron
Isobutyl alcohol
Lactic acid
Lead
Lead arsenate
Lead carbonate
Lead nitrate
Lead sulfate
Lecithin
Legumin
Leucine
Lithium carbonate
Lithium chloride
Lithium nitrate
Magnesium
Magnesium carbonate
Magnesium chloride
Magnesium nitrate
Magnesium oxide
Magnesium sulfate
Malic acid
Maleic acid (Na salt)
Manganese
Manganese carbonate
Manganous sulphate
Mercuric chloride
Mercurous chloride
Mercury
Methyl alcohol
Morphine (hydrochloride)
Mucin
Myronic acid (K. salt)
Naphthalene
Naphthylamine
Naphthylamine (hydrochloride)
Neurine
Neurine (neutralized)
Nickel
Nickel chloride
Nickel nitrate
Nickel sulfate
Nicotine
Nitric acid
Nucleic acid
Nuclein
Oil of bitter almond
Oil of camphor
Oil of eucalyptus
Oil of lavender
Oil of lemon
Oil of mustard
Oil of origanum
Oil of peppermint
Oil of pine
Oil of rosemary
Oxalic acid
Oxamide
Palladium
Palladium nitrate
Paraffin
Peptone
Petroleum
Petroleum ether
Phenol
Phenylalanine
Phloroglucin
Phospho tungstic acid
Phosphorus pentachloride
Phytin
Picoline
Picoline carboxylic acid
Piperidine
Piperidine (hydrochloride)
Piperidine (neutralized)
Piperonal (heliotrophine)
Platininic chloride
Platinum
Potassium bichromate
Potassium bromide
Potassium chromate

Potassium cyanide	Sarcine	Telluric acid
Potassium ferricyanide	Selenium	Tellurium
Potassium ferrocyanide	Silicon tetrachloride	Tetranitromethane
Potassium iodide	Silver	Thallium
Potassium oxalate	Silver nitrate	Theobromine
Potassium persulfate	Silver oxide	Thorium nitrate
Potassium silicate	Skatol	Thymol
Propionic amides	Sodium acetate	Tin
Propionitrile	Sodium arsenate	Tin tetrabromide
Propyl alcohol	Sodium arsenite	Tungsten
Propyl alcohol (iso)	Sodium bicarbonate	Turpentine
Pyridine	Sodium carbonate	Turpentine venetian
Pyridine (hydrochloride)	Sodium chlorate	Tyrosine
Pyrocatechin	Sodium chloride	Uranium nitrate
Pyrogallol	Sodium fluoride	Urazine, para.
Quinic acid	Sodium formate	Urea
Quinine (hydrochloride)	Sodium nitro-prusside	Uric acid (Na salt)
Quinoline	Sodium silicate	Uvitonic acid
Quinone	Sodium sulfite	Valeric amides
Radium chloride	Solanine	Vanadium sulfate
Resin	Strontium carbonate	Vanillic acid
Resorcin	Strontium nitrate	Vanillin
Rhodium	Strychnine	Xanthine
Ricin	Succinic acid	Xylol
Rubidium chloride	Sulfur	Zinc
Ruthenium	Sulfuric acid	Zinc sulfate
Salicylic acid	Tannic acid	

This is by no means a complete list; but it is suggestive of the large number of chemicals which may be looked upon as available for application to soils, in addition to the small list which has been given of recognized plant food materials. Since, the substances contained in this larger table are not of general applicability, they are to be used only in such special cases as a diagnosis of the soil indicates that they may be safely and economically used. It will be noticed that this list contains such common soil amendments as lime in different forms, for the use of which there are fairly satisfactory methods of diagnosis and which may now be applied only where tests indicate that it will be useful.

This list of 296 substances therefore would form a "pharmacopoeia" of substances to be used only in special cases and with specific crops as indicated by a diagnosis. There is no more justification for including any of these in a fertilizer formula for general use than there would be for including drugs in a general way in foods because they might be beneficial to some people under certain conditions, a practice which is prohibited by law.

Objections may be made on the ground that it is much more difficult to diagnose soil troubles than to diagnose the diseases of man; but this is begging the question, for the difficulty should be overcome through the development of methods and the education of farmers properly to diagnose soil conditions, as has been done in the long

study of the diseases of man and of the appropriate remedies to be used.

If the essential differences between the admitted mineral plant foods and this "pharmacopoeia" material is recognized and if soil investigators and users are willing to face the facts and to apply these things intelligently to the soil, there seems no sound reason why we should not go back to the beginning of present fertilizer practice and use the chemicals that were then used to find the basis of the fertilizer necessities. These would be comprised in the simplest and most concentrated salts that can be made by present methods and that can be mixed together in all proportions without change, namely ammonium nitrate, ammonium phosphate, potassium phosphate, and potassium nitrate.

The adoption of such a chemical basis for the main fertilizer manufacturing industry of the country would insure any desirable future extension of the fertilizer trade of uniform materials in the most concentrated form in which they could be shipped and used and would in no way prevent the use of present forms of waste and by-product material so far as they are available and can be supplied economically to the farmer.

Objections may be raised to the elimination of organic material on two grounds: First, it may be argued that they are good conditioners and tend to keep fertilizers in the best possible texture for application to the soil and from the dilution resulting from their use make it easier for the farmer to distribute the fertilizer on his soil. No answer is required to this criticism, as experience shows that the valuable organic ammoniates are not available for the more extensive use of fertilizers which is demanded and indicates that it will be necessary to depend more and more upon chemical substances and to devise more efficient methods for applying fertilizers in concentrated forms.

The second objection which may be urged is that the organic matter itself may furnish food to the soil organisms. In turning under a leguminous crop or in applying from 5 to 40 tons per acre of stable manure the amount of organic matter supplied to the soil organisms from which they derive their energy is very considerable, while the amount of organic matter contained in an application of 400 pounds of commercial fertilizer per acre would be exceedingly small. Furthermore, the availability of the nitrogen of the nitrogenous organic materials is generally compared with the efficiency of nitrogen in the form of nitrate of soda and unit by unit of nitrogen they are generally shown to be less efficient than the standard.

It would appear, therefore, that with the advances that have been made in the fixation of nitrogen in the form of ammonia gas and in the oxidation of this gas to nitric acid and the development of liquid phosphoric acid from phosphate rock, there is a proper chemical basis, under proper control as to production, for a fertilizer industry based upon the use of such simple salts as ammonium nitrate, ammonium phosphate, potassium phosphate and potassium nitrate.

NITRIFICATION STUDIES WITH YAHOLA SOILS[1]

HENRY MURPHY[2]

In recent articles in this JOURNAL,[3] data were presented which show the influence of lime and organic matter (manure) applied to two typical soils of the Great Plains region (Vernon and Kirkland soil series) on plant characteristics and nitrate production.

The purpose of this article is to give briefly the influence of these materials when used on the Yahola soil of the same region. The Yahola soil is a bottom land soil formed principally from the Red soils (Vernon). The Red lands formed from disintegrated and weathered sandstone generally occupy the rough to steep hills and erode quite badly, the material washing away and forming a rather deep soil generally of a sandy nature. This newly formed soil is classified Yahola. The subsoil is generally of a lighter texture and color than the surface soil. Very often the first two or three inches of the surface soil is of a sticky sandy-clay nature, and is sandier below, becoming more open as the depth increases. The color of the surface is reddish brown, while the subsoil lightens to an almost salmon shade. The surface drainage is generally good but the under drainage is such that a large amount of moisture is lost.

The soil type used for this experiment was Yahola very fine sandy loam. The surface soil is a little heavy, but the general soil is moderately open in character.

The rate per acre of the various treatments and general results as to nitrates produced found are given in Table 1. The soil has received the outlined treatments twice since the experiment was started, once in 1917, and again in 1921. The nitrate data given are the results of pot tests using 100 milligrams of ammonium sulfate as the material to be nitrified for each 100 grams of soil

[1]Contribution from the Department of Agronomy, Oklahoma Agricultural and Mechanical College, Stillwater, Okla. Received for publication March 1, 1924.
[2]Associate Professor.
[3]See Jour. Am. Soc. Agron. 15:442–444 and 16:130–136.

(calculated on over-dry basis) and incubating for a period of four weeks at room temperature.

TABLE 1.—*Showing number of milligrams of nitrates per hundred cubic centimeters of filtrate.*

Month	Plot No.	Treatment	1921	1922	1923	Average
June	1	Check	3.200	10.725		6.962
	2	5 tons limestone	11.035	30.770		20.902
	3	2.8 tons quick lime	9.410	25.000		17.205
	4	5 tons limestone and 8 tons manure	10.000	32.050		21.025
	5	2.8 tons quick lime and 8 tons manure	10.666	34.615		22.640
	6	Check	2.176	12.115		7.145
	7	3 tons limestone	7.272	18.675		12.973
	8	1.68 tons quick lime	8.420	32.050		20.235
	9	3 tons limestone and 8 tons manure	8.000	20.510		14.255
	10	1.68 tons quick lime and 8 tons manure	7.272	22.435		14.853
July	1	Check		6.533	5.400	5.966
	2	5 tons limestone		16.533	13.333	14.933
	3	2.8 tons quick lime		17.599	19.000	18.299
	4	5 tons limestone and 8 tons manure		20.000	23.466	21.733
	5	2.8 tons quick lime and 8 tons manure		26.800	15.400	21.100
	6	Check		7.466	8.300	7.883
	7	3 tons limestone		8.533	15.866	12.199
	8	1.68 tons quick lime		19.733	16.799	18.266
	9	3 tons limestone and 8 tons manure		18.133	17.133	17.633
	10	1.68 tons quick lime and 8 tons manure		21.599	19.466	20.532
Aug.	1	Check	1.115	8.200	8.200	5.838
	2	5 tons limestone	6.540	18.133	26.000	16.891
	3	2.8 tons quick lime	3.295	19.733	27.200	16.743
	4	5 tons limestone and 8 tons manure	6.700	20.532	22.933	16.722
	5	2.8 tons quick lime and 8 tons manure	5.145	17.333	29.200	17.226
	6	Check	1.165	6.000	7.146	4.770
	7	3 tons limestone	2.790	16.266	10.133	9.730
	8	1.68 tons quick lime	4.400	16.253	20.533	13.729
	9	3 tons limestone and 8 tons manure	3.665	15.719	12.666	10.683
	10	1.68 tons quick lime and 8 tons manure	3.480	15.200	12.800	10.493

The data presented in Table 1 leave no doubt as to the influence of lime on nitrification in the soil, the treated soil generally producing from three to four times the amount of nitrates produced by the untreated soil.

TABLE 2. *Effect of rate of application of lime on nitrification in Yahola soil.*

Treatment	2 yr. Ave. June	2 yr. Ave. July	3 yr. Ave. August
5 tons limestone or equivalent quick lime	19.053	16.616	16.817
3 tons limestone or equivalent quick lime	16.604	15.232	11.729
Check	7.053	6.924	5.304

The data presented in Table 2 show that the rate of application of the lime has an effect on the amount of nitrate produced. As a general average, the soil receiving the heavier rate of lime produced the largest amount of nitrates. This is in accordance with data secured on the uplands from which Yahola soil is formed, as shown in preceding papers.

TABLE 3.—*Effect of different forms of lime on nitrification in Yahola soil.*

Treatment	June	July	August
Average of all limestone treatments............	16.937	13.566	13.310
Average of all quick lime treatments...........	18.720	18.282	15.236
Average of all check plots....................	7.053	6.924	5.304

The influence of the forms of lime on this bottom land is practically the same as on the corresponding uplands, since land treated with caustic lime produced the largest amount of nitrates. This is shown in Table 3.

TABLE 4.—*Influence of manure on nitrification in Yahola soil.*

Treatment	June	July	August
5 tons limestone or equivalent quick lime.......	19.053	16.616	16.817
5 tons limestone or equivalent and 8 tons manure	21.832	21.416	16.974
3 tons limestone or equivalent quick lime.......	16.604	15.232	11.729
3 tons limestone or equivalent and 8 tons manure	14.554	19.082	10.588
Check......................................	7.053	6.924	5.304

Data presented in Table 4 do not show that nitrification is increased to any great extent when manure is used in connection with lime on this soil. This also applies to the uplands from which this soil was formed. With the uplands however, manure produced its greatest effect when applied with the lighter application of lime, while for the bottom land soil manure gave the highest returns of nitrates when used with the larger application of lime.

TABLE 5.—*Effect on kafir plants grown on Yahola soil of treatments with different forms of lime, with and without manure.*

Plot	No. of stalks measured	Effect on height of stalk Mode (ins.)	Effect on height of stalk Mean (In.)	Effect on circumference of stalk Mode (In.)	Effect on circumference of stalk Mean (In.)
1	94	51	50.56	2.8750	2.93
2	119	54	50.10	2.8750	2.82
3	125	52	50.35	2.8750	2.76
4	116	54	52.30	2.5000	2.88
5	105	55	52.14	3.0625	3.02
6	98	53	48.88	2.9375	2.94
7	110	48	49.10	2.8750	2.93
8	105	48	49.44	3.0000	2.95
9	100	51–52	49.58	3.1250	3.00
10	106	47	48.82	2.7500	2.90

As to the influence of the treatments on the height of stalks and circumference of stalks shown by the data in Table 5, no great benefits can be noted. This is opposite to the case for the upland soils. This may be due to the fact that the subsoils of the upland soils are heavy in character, and for the Kirkland, hardpan in nature, while for this bottom land soil the subsoil is very open—a difference in which either the stimulating effect of lime on the plant from the plant

food standpoint or the effect of lime on the physical condition of the soil would probably be more favorable to pronounced results on the tight upland soils. It is known that these uplands are only moderately supplied with plant food, which perhaps means that they have only a limited amount available at any one time, and that the subsoils tend to restrict root extension and moisture movement into the lower subsoil.

AGRONOMIC AFFAIRS

COMMITEES ON REGISTRATION OF VARIETIES OF WHEAT, OATS AND BARLEY

President M. F. Miller, of the American Society of Agronomy, has announced the appointment of the following members of the Society as the three committees on registration of varieties of wheat, oats and barley, respectively, which were authorized at the annual meeting of the Society held in Chicago on November 12, 1923:

Oats		Barley	
T. R. Stanton, Chairman	(3 yrs.)	H. V. Harlan, Chairman	(3 yrs.)
W. C. Etheridge,	(2 yrs.)	R. G. Wiggans,	(2 yrs.)
J. H. Parker,	(1 yr.)	E. F. Gaines,	(1 yr.)

Wheat	
J. Allen Clark, Chairman	(3 yrs.)
H. H. Love,	(2 yrs.)
A. C. Arny,	(1 yr.)

The powers and duties of these committees are described in detail in the report of the Committee on Methods of Registration of Varieties of Wheat, Oats and Barley, which was presented at the annual meeting and is printed in full in the published Minutes (see JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY, 15:527–529, December, 1923).

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1. COORDINATING THE EXPERIMENT STATION AGRONOMY PROGRAM AND THE EXTENSION PROGRAM[1]

A. J. MEYER[2]

Harking back to the days when the Smith-Lever Act was in the making, most of us will recall the eloquence and emphasis with which statesmen and scholars proclaimed the existence of vast accumulations of agricultural information at the various state agricultural colleges.

We were assured—as we assured ourselves and others—that the wielder of test-tube, scalpel and microscope had wrought mightily and well. Meanwhile agriculture—referring specifically to that of the open country, rather than the laboratory—languished. The hideous specter of a mal-adjusted cropping system, a depleted soil and a Nation crying for bread, stalked silently tho menacingly abroad in the land. Some means must be provided without delay to bring permanent relief to this developing situation by carrying to the farm this stored-up knowledge now in the possession of the colleges.

The Smith-Lever Act came to the rescue. It became the law of the land. Over it the United States Department of Agriculture waved its fairy wand of authority and, presto!—there arose in each state an agricultural extension service. Hard fares it now with the hideous specter of agricultural impoverishment. No longer does he roam the countryside alone. Close on his heels presses an untiring foe—half man, half flivver. He is called "county agent." To him is assigned the happy task of personally delivering to each farmer his proper share of the undivided surplus of agricultural knowledge which has accumulated thru the years at the agricultural college.

[1]Paper read as a part of the symposium on "Extension Work in Agronomy," at the meeting of the Society held in Chicago, Ill., November 13, 1923.

[2]Director of Agricultural Extension Service, University of Missouri, Columbia, Mo.

But as the task unfolds, complexities arise. Farmer Jones listens politely to suggestions. He cordially invites the agent to dinner—Mrs. Jones and the girls will be interested in meeting this likable young chap—not to mention the hired hand. Jones agrees most heartily with all the ideas of the new agent. Yes, he has always believed in crop rotation since he first began to read about it twenty years ago. He's seen how acid phosphate has been giving good results for these experiment station fellows every year for the past eight or ten years. He ought to use lime on every foot of his farm; he's believed that ever since his father used it with such good results thirty years ago. But somehow all these things don't quite fit into the Jones system. Fine ideas, though, for those who can use them. Worth pushing in the county. Splendid notion—having a county agent. Jones is for it.

Under stimulating experiences such as this and others of similar character, representing greater or less degrees of stimulation, the extension worker very soon reached two important conclusions: first, that the agricultural college had done a rather thoro job of distributing its new knowledge about as fast as its research division had been able to turn out new knowledge; and second, that the immediate and, by far, most pressing task confronting the extension division was to lead farmers to *adopt* practices the value of which they already conceded.

Having thus analyzed the extension problem in its grosser aspects, we are ready to proceed to a more specific consideration of the question before us, that of coordinating experiment station and extension activities.

Prior to the passage of the Smith-Lever Act, much (in some colleges, most) of the extension work of the institution was done by experiment station men. Under this system of dual functioning, there was of necessity the very closest coordination of investigational and extension work.

With the organization of the extension service, station men have been steadily losing their intimate personal contact with farm people and, correspondingly, with farm problems. If I understand the trend of development in the colleges, the direct contact between the research worker and the farmer in whose interests he labors, grows increasingly less. The extension service has only one place in the college organization. That place is squarely between the research division and the farm, a connecting link and likewise a separating link between the two. This situation must inevitably cause the investigator to drift from his farm moorings unless a sure way is

maintained to bridge the ever-widening gap. If comparisons may be permitted, I venture the assertion that failure properly and permanently to bridge this gap will result in greater disaster to the extension division of the college than to its research division. The extension specialist should and must, therefore, assume the responsibility of keeping the department, which he represents in a subject matter way, fully informed with reference to the needs of the field as he discovers these needs in the performance of his regular duties. The initiative should rest with him in this matter, even though at times he may render no greater service than that of confirming knowledge already in hand which has come to his department thru other channels.

The responsibility of the experiment station to the extension service is equally clear. No college can function effectively and with credit to itself in the extension field unless its research division shapes its program with the fullest regard to the institution's extension needs.

In order that this paper might not deal entirely with abstractions, the writer took the liberty of addressing a questionnaire to thirty-nine extension agronomists in something less than that number of states.

The questionnaire was as follows:

1. List in the order of their importance five questions you meet in your field work which cannot be satisfactorily answered without additional research work by your state experiment station.

2. Is your experiment station now engaged on projects which will give you the answers to questions listed under (1) above? All? If not, how many?

3. Were these experiment station projects instituted at your request or suggestion in order that you might have experimental data needed in your field work? All? If not, how many?

My motive in the case of each of these questions will appear in my conclusions based upon replies received from twenty-seven of these extension agronomists. Two of the number stated that they were not confronted by problems which stood out as especially needing attention. Ten agronomists did not reply. Since this number represents an average mortality rate as questionnaires usually go, we need not speculate as to what the ten might have said had they submitted replies.

The following conclusions are drawn from the replies received:

1. The extension agronomist is keenly conscious of the fact that his success is dependent to a very large degree upon the efficiency of the research division of the institution he represents. He realizes that superior methods and painstaking mechanical organization of

his work cannot accomplish results unless he has constantly at hand information somewhat in advance of the common knowledge of the best farmers with whom he works. This knowledge can only come from scientific investigation.

2. The problems, from the extension worker's standpoint, demanding further study are preponderatingly those of limited regional application, problems which apply to individual states or to special regions within individual states. A rough classification of the one hundred eleven questions submitted places them in twenty-nine groups. One question appears nine times; two questions appear three times each; three questions appear two times each. This statement in itself indicates that there are no general outstanding questions applying to large numbers of states. Each state has its own special problems and, for the most part, these problems are confined to limited areas within the states.

3. More information on legumes and fertilizers is needed in practically all sections of the United States. 17.1 % of the questions listed in replies to the questionnaire are concerned with fertilizers; 26.1% with legumes to which might very properly be added an additional 7.2% of lime inquiries, the latter being, of course, closely associated with the legume problem.

4. There is still considerable demand for information on processes; e. g., how to harvest soybeans, how to treat for loose smut, and the like. 20% of the questions submitted were in the nature of "how-to-do" questions. Farm processes are still a problem with us.

5. Most of the problems confronting extension workers are in process of attempted solution by the experiment stations, 82.9% according to the results of the questionnaire.

6. With but four exceptions, extension specialists replying to the questionnaire indicate that they have been consulted and their needs considered in the shaping up of the research activities of the subject matter departments with which they are associated.

This last point deserves special comment. It sounds the keynote of the full-functioning, unified department in which every member is made to feel his responsibility for departmental strength in its every activity. It betokens a healthy situation as regards the coordination of experiment station and extension activities. It speaks well for our present status and promises well for the future.

Probably the most significant thing brought out by the questions submitted from the various states is the great need for work which combines extension and investigational features. It may be unorthodox to so much as suggest a combination of experiment station

and extension service activities in the same project. Yet, work of this kind is needed; moreover, from the standpoint of the institution itself, much time and money can be saved by a wise combination of the two lines of effort. As an illustration, we have, in Missouri, a persistent demand for information on cotton production. The cotton-producing area of Missouri presents a wide variation in soil types and texture. The adaptation of a system of cotton growing to each of these different types is a problem confronting the agricultural college. The cotton growers of southeast Missouri cannot afford to wait two or three years while the experiment station works out the answers to such questions as proper varieties to plant, space between rows, spacing in the rows, fertilizers, methods of tillage, control of insect enemies, and the like. The extension service will not be fulfilling its function if it neglects its opportunity to help farmers with their cotton problems. The institution as a whole will lose support and fail in its duty, if it does not at once bring to the cotton growers of southeast Missouri all its available facilities. What is needed in Missouri at once is to establish, on all the soil types of the cotton-growing areas, demonstrations which farmers may study through the season and from which farmers may draw their own conclusions with reference to the various phases of cotton production. While the farmer is learning, the college will be learning. To this extent, these demonstrations may be regarded as investigational in character. Their extension value is evident, particularly to those of us who know that farmers are generally more interested in watching a demonstration whose outcome is more or less a matter of question and doubt. Human nature is very much alike the world over.

Apparently every state reached by the questionnaire referred to above has problems identical with the cotton problem of Missouri. They are all problems that must have immediate attention. Farmers will rightly criticise the institution which, in its attempt to maintain a clear differentiation between experiment station work and extension work, proceeds deliberately to experiment one year and demonstrate the next. The two must go forward simultaneously and together.

Finally, may I leave the following thought with you. It is neither new nor original, but it will stand repeating. Coordination between the experiment station and the extension service is important. Each must have a program which harmonizes and supplements that of the other. Neither will reach its maximum of efficiency, however, until the college proper shall develop a long-time program, directed toward positive goals, and then bring to bear upon the accomplishment of that program all the resources which the college has at its

disposal. The resident teacher will have his part; the research man will have his part, and the extension worker his. Then, and not until then, will we have perfect teamwork. When that time comes, not only will research man and extension man sit about the council table together to decide departmental programs, but department will sit with department, to the end that each may play its proper part in a great unified institutional program.

2. WHAT PROPORTION OF THE FACTS PUBLISHED BY THE EXPERIMENT STATION ARE USABLE IN EXTENSION WORK[1]

H. C. RAMSOWER[2]

When I began to think seriously about the subject assigned me for this paper I decided that a proper procedure would call for an examination of a number of annual reports of agricultural experiment stations in an effort to answer the question with some degree of accuracy. After turning through a few such reports, I came to the conclusion that such a study would be essentially useless for the following reasons: first, the whole study would be based upon my individual conception of what an extension project is; second, when an experiment suitable for station work is proposed the question "Will this piece of work if successfully concluded be adaptable to an extension project" may be, perhaps should be, wholly irrelevant; and third, ideas as to the proper subject for an extension project will necessarily change as progress in the extension field is made.

After tabulating the work reported by one station as completed, or in progress, during one year, I estimated that approximately one-half of the experiments under way had in them material that might be used for active extension projects. The other half, none the less valuable, presumably adding materially to the sum total of scientific knowledge, were nevertheless so far removed from the possibility of practical application as to be useless for present day extension purposes. Further study would, no doubt, show that much of this latter class of work is essential in the solution of other and more practical problems. The work of experiment stations must always afford the basis for extension projects dealing with subject matter. This work should, no doubt does, look forward in all instances to the solution of some agricultural problem. The final solution, however, may be in the distant future, in which case the problem is a most excellent one from

[1]Paper read as a part of the symposium on "Extension Work in Agronomy" at the meeting of the Society held in Chicago, Ill., November 13. 1923.

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the standpoint of the station yet wholly unready for the use of the extension specialist.

Again, a station problem may be solved to the satisfaction of all concerned. It may be approved as a practice that should have wide application in the state, yet farmers may not be in position to install the practice. Such a problem, therefore, should not be selected by the extension specialist. The burden seems to fall on the specialist and those with whom he advises. He is close to the real problems of the farm. He is familiar with the progress of farmers in his particular field. To select an appropriate project becomes his first task.

I found myself, therefore, giving thought rather to what I believe to be a more fundamental and a more timely phase of this subject, namely, "What constitutes a good extension project?" I trust I may be pardoned if, in discussing this theme, I am departing from the original plan of those who made up the program.

The work of the extension specialist must be measured in terms of the number of farmers that adopt practices which he recommends rather than in terms of principles enunciated by word of mouth, by the printed page, or by the demonstration. With such a yardstick applied to our general extension activities our efficiency curve runs extremely low. One remedy is a simplified project.

Among our first efforts in extension work was the extension school. This project merely moved the college class room out into the rural community where the work was made more available to those for whom it was intended. The principles set forth at such meetings were many and varied. The whole gamut of what, why, when, and how, was run. Much good was done, no doubt. Just how much no one knew or could readily ascertain. The demonstration then came on. It frequently accompanied the school and improved it, too. It is now a part of every extension worker's equipment. Our projects are planned to demonstrate this or that. The principle underlying the plan is sound.

Our projects, however, have been too complex. We have sought to demonstrate too much at one time. Too often, we have attempted to sell our customer a complete outfit—suit, hat, shoes, overcoat—and failed because the size of the purchase scared him out. In hunting for the problem to form the basis for a project we have used a large-bore shot gun when a full-choke or even a rifle would have been a better selection.

Let me illustrate. We go out before a group of farmers and give a talk on soil improvement. We discuss drainage, tillage methods, the use of barnyard manure, commercial fertilizers, and the growing of

legumes. Each of the phases covered is part of a rational soils program. The farmer should do all of the things suggested. He goes home thinking of the plan placed before him. The next evening sitting before his kitchen fire he soliloquizes—"They told me I must drain my land, if it is wet. I wonder what is meant by wet! How much will it cost me to drain? Can I afford to do it? If Brown handled tile I might try some; but he doesn't. I might even get some tile shipped in, if there was a ditching machine in this neighborhood to put them in for me. I should like to try it anyhow. They told me to use commercial fertilizer. They said something about feeding the soil and not the crop. Now I wonder what my soil needs. Jones handles several brands. I guess he knows fertilizers pretty well. I'll wait till he comes before I decide. And I must have a legume in my rotation. Soybeans sound good to me. Easier to grow than alfalfa. I wonder how beans are planted. I wonder where I can get some seed? How do they harvest those beans anyhow. This farming business is pretty complex. I don't know what to do first. That was a mighty good talk, though, I'd like to hear that young fellow again sometime after I have had a chance to think these things over." The sale was lost. He might have bought a pair of shoes.

The point I wish to make is this. Our projects must more and more be drawn in terms of simple, single practices. Out of the mass of accumulated station evidence, there must be taken a very small number of established facts and these sold in successive installments. The dairy specialist carries a project in improved feed practices. He attempts to set forth the principles underlying feeding and balancing of rations. The practice involved is complex. The average man will not get it and hence will not improve his practice. It would be far more to the point to recommend a few simple rations, telling exactly how to make them up in terms of bucketfuls, if you please, rather than in terms of percentages. Such recommendations will be adopted and put into practice. Joe Wing was once addressing a class at the Ohio State University when some one asked what he considered the best make of lime spreader. He named a prominent spreader without hesitation. His answer was specific and to the point. The questioner was satisfied. My answer as an instructor would have been quite different and much less satisfying. It is not always easy, perhaps not always possible, to be specific. It sometimes takes courage and a little daring to make specific practice recommendations. We must not go beyond the bound of reason; but if our efficiency curve is to rise more rapidly than in the past, we must simplify our projects.

Our projects have not always been thought through to a definite, logical end. It is useless to demonstrate the need of lime in a community if getting lime onto the farm is the chief factor controlling the spread of the project. Establishing the demand may logically precede the task of satisfying that demand. But the project may be questioned if it does not at least have a solution ready for the more fundamental phase of supplying the lime. There is no logic in advocating the wide use of an improved variety of wheat unless the demand for it can be satisfactorily met. A project promoting the use of disease-free northern grown seed potatoes will be incomplete unless a satisfactory source of seed is known and machinery is available for bringing it into the community. If drainage is the problem, perhaps first attentions should be given to better ways and means of getting tile into the community. Or, this being properly cared for, it may be that the big difficulty standing in the way of drainage progress is labor. There is little use in talking or demonstrating systems, depths and distances, until the problem of getting the tile into the ground is worked out. First effort should, therefore, be directed toward the wider use of ditching machines, if that be the solution of the labor question. Our projects must not only strike at simple, single practices, but they must also reach those that are fundamental. They must place first things first.

Our projects must be drawn to meet the needs and progress of a farmer who is near the average in practice. Our extension work is largely done with what might be termed the upper ten percent of the farm population. A fairly large number, in this group, are already following the practices recommended by station and extension. In this group, there is found the breeder of purebred livestock and purebred seed—the neat, progressive, prosperous farmer. The station must keep in advance of this group in the discovery of new truths on which new and improved practices may be based. But we have a tendency to work with this group too exclusively. We plan our projects for this group. We think of the needs of this group and note what progress its members made in our work during the year. Another year we devise some new project for them. The question I am raising is this "Is a project designed primarily for this upper-ten group suitable for wide dissemination among average or below-average farmers?" To illustrate, our poultry specialists work intensively with a small group of poultry-farm demonstrators. They are good poultry growers. Their practices are of the best. They house their birds in faultless manner; they feed mash; they breed and select the best layers; they cull; they rotate yards;

they use disease-preventive and curative measures; they adopt any good new practice at once. The specialist is too likely to think of these men when he plans his new projects. Possibly, the average, farmer who keeps a good many birds, is doing none of the things the semi-professional poultry grower is doing. A project for him must begin with fundamentals and keep at fundamentals for some time to come.

Our projects must not be dropped entirely from the specialist's program until the idea is installed by nearly fifty percent of those concerned.

A few days ago I had the privilege of listening to a series of talks given by Dr. W. W. Charters of the University of Pittsburgh on "Methods in Education." He gave me a combination of simple words in which is expressed the whole function of extension and hence the function of the specialist. I should like to pass them on to you.

He was comparing procedure in pure research and practical research. He stated that there are two steps in pure research; namely, (1) selecting the problem, and (2) solving the problem. He said that, in practical research, there are five steps: (1) surveying the field; (2) selecting the problem; (3) solving the problem; (4) installing the solution; (5) maintaining the practices. Survey. Select. Solve. Install. Maintain. Let every extension worker take firm hold of those five words.

It is true that the practice of the best farmers has a wholesome effect on the man of average attainments. It is necessary and usually best to sell our wares to the easiest customers. But our task is only begun when, too often, we lay it down as finished. The mortality in extension projects from year to year is tremendous. Where is the trouble? Were they not worth while pushing until the practice became quite general? Or do we feel that somebody else must take the responsibility for spreading practice after that practice is successfully demonstrated in a few isolated communities?

I am not assuming that the specialist must take sole responsibility for the complete installation of his projects. The county agent must and will do his part. The specialist must, however, bear the chief responsibility. He sells his projects to the county agent. The county agent begins the installation. The specialist puts on a few demonstrations and, too often, stops there. He has only begun. Somehow, someway, that project must be continued until a much larger portion of those interested have been reached and have made the installation, than has heretofore been the case.

Again I refer to the statement, made in the beginning, that a

specialist's work will be measured by the extent to which the projects for which he is responsible become the accepted practices of those for whom they were intended. Aside from a consideration of the method used to install the project, the type selected will help or hinder installation. Our task, then, is to survey the field to determine fundamental needs in each line of work; to select a simple problem; to discover among station evidence, or elsewhere, a solution for that problem; to install the solution; and then to see that the practice is maintained. All this means simplified projects, thoroughly thought out, planned for average customers and then aggressively sold.

3. WHAT PROPORTION OF THE PRACTICES PROJECTED BY THE EXTENSION SERVICE ARE ADOPTED BY FARMERS[1]

O. S. FISHER[2]

It would seem that the subject for discussion at this time strikes right to the foundation of all extension work.

The fundamental idea back of the Smith-Lever law and, even before that, in the extension work carried on in the Cotton Belt states, was that demonstrations, carried on in connection with the farm and the home life of the people, should tend to modify existing conditions and make the farm more profitable and the farm home a more pleasant place to live. If the farmer does not adopt the practices that are demonstrated to him on his own farm then the work is a failure.

There are four distinct steps in the extension program and unless all of these steps are carried through to the ultimate conclusions the extension work usually does not succeed. These are: 1. The extension worker must be able to find the fundamental problem that is needing solution. 2. He must find an answer to this problem that is both economically sound and practical enough to fit into the operations of the average farm. 3. Having found the solution, this must be demonstrated on a sufficient number of farms well scattered over a county that the farmers may see that the solution is practical and profitable for them to follow. 4. Having demonstrated that the practice is sound, it must then be sold to the people.

Let us analyze, for a moment, these four fundamental steps in extension work.

First, there is the matter of studying conditions, in order to de-

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termine the fundamental problems of the farmer. In the early years of extension work, little attention was given to a real study of the farmer's problems. The agent was placed in the county, and was considered both by the farmers and by the people at the college more in the light of a "farm doctor" to answer the calls of the individual farmer. He did very little definite demonstration work. It has only been in the last few years that constructive thought has been given to the working out of definite county and state programs of extension. At present, I do not know of any state where the extension workers do not feel that this first step is fundamental before any real progress can be made.

Second, in finding a solution for the farmer's problem, the extension worker usually finds it necessary to call into conference the scientists of his own institution and of the United States Department of Agriculture, and the leaders of agriculture and the thinking farmers in the state. The farmer's view point is valuable and necessary. The United State Department of Agriculture can help, especially with problems of more than state-wide importance; but the extension workers of a state must look primarily to their own institution for guidance.

Third, there is the demonstrating of the solution of the problem. Probably no phase of extension work has been more under discussion than the question of demonstrations, as to what is a demonstration, how it should be carried on, how many should be conducted in a county and the length of time the demonstration should be continued. It is coming to be recognized, however, that single practice demonstrations are more generally successful than complicated demonstrations. These can be put on with very little epxense to the farmer, with very little disarrangement of his farm work, and are easily understood by himself and his neighbors. Concerning the question of how many demonstrations should be conducted in the county, we are finding that in really successful extension work the agents are striving to put on enough demonstrations to make them easily available to all farmers in the county. One or two demonstrations in a county usually mean nothing at all in modifying farm practice. In the same connection, we are finding there is a very definite limit to the length of time a demonstration should be carried on. It is easily possible to carry a demonstration to the place where it means nothing to the farmers, because it has lost its novelty and its ability to attract their attention and modify their farm practice.

Fourth, the last step in extension work is the one that is perhaps least understood, and yet is just as important as the other three,

namely, securing adoption of the practice by the farmers, called by whatever term we wish to use. For lack of a better one, I will use the term "selling the practice." Probably no other one thing has been responsible for a greater number of failures in extension work than neglecting this part of the extension program. At first thought it would seem that if a practice is profitable, easily followed and easily adapted to the general practice of the community, the farmers will adopt it without any undue pressure. This, however, does not seem to be the case. *The real measure of extension work is not how many demonstrations an agent puts on in his county, but how many farmers he is able to reach and to get them to adopt the practices he has demonstrated.*

It may be said that "selling the practice" to the farmer is beyond the scope of the extension worker, that this should be left to the commercial interests; but we are finding that unless the extension worker, whether in the county or in the state, helps to make easily available the material for putting into practice the things demonstrated only a very limited number of farmers will adopt the practice.

I have in mind a county in New England. Dairying is the principle source of farm income and the foundation of profitable dairying is to produce as large an amount of home grown feed as possible, especially roughage. Yet a study of this county indicates that there is less than 700 acres of all legume hay grown in that county out of a total of 71,000 acres of hay and forage. The county agent in that county has been demonstrating alfalfa, sweet clover, soy beans and common red clover, and yet there has been no increase in acreage, in some of these things an actual decrease. The problem is that they cannot successfully grow legumes without limestone and limestone delivered at the farmer's siding will cost from $10 to $15 per ton. The farmers believe in limestone, but after six years of demonstration work only thirty-five farmers in that county are using lime simply because they feel that they cannot afford to buy it. Yet almost every farmer in that county has an outcrop of limestone somewhere in his fields or pastures. The solution of that problem would seem to be developing local sources of lime and in this way increase the acreage in legume forage and decrease their annual feed bill, which amounts to almost three quarters of a million dollars. To show the results of making it easy to follow the recommended practice, I wish to cite the experience in a Middle West dairy county. For years the farmers of this county have been buying feed, and almost no alfalfa or other legumes were grown. The amount of limestone used annually was from 100 to 150 tons. In 1920, an enter-

prising extension man developed four or five local quarries with portable crushers. As a result, in 1921, more than 2,300 tons of limestone was ground and used in that county; and in 1922, more than 3,700 tons, and the acreage of alfalfa, in 1922, increased by more than 1,500 acres.

There are many other instances that I could cite to show that it is just as important to insure ample supply of material, whether it be better seed, limestone or purebred cattle, as it is to demonstrate the value of these things.

In collecting material for this discussion, after considerable study, it was decided that the only way to get an answer to this question was by a study of the work from the time it originated until the present, endeavoring to obtain as accurate a measure of definite results as possible. In making this study, I have included thirteen states from Vermont in the east to Alabama in the south and Oregon in the west. I have with me charts outlining the results of detailed study of both the agronomy work covering soils and crops and the livestock work in one or more counties from each of these states. Time will not permit a detailed discussion of each of these charts. I will, however, present a few examples to show that when the four fundamental steps in extension work have been properly followed the work has been reasonably successful.

Results of Agricultural Extension Work in Certain Counties

COUNTY A.—A dairy county with 80,259 dairy cattle and dairy products valued at $6,806,719, according to the 1920 census.

	In 1914	In 1923
Acres clover grown	20	30,000
Tons limestone used	50	3,000
Acres pastures improved	15	400
Farms growing corn for silage	5	215
Acres silage corn grown	40	1,860

COUNTY B.—A Black Belt Cotton County

	In 1913	In 1917	In 1923
Cotton Standardization			
Number of farms		50	300
Acreage involved		234	1,500
Green Manuring for Soil Improvement			
Velvet beans, No. of farms		80	200
Acreage		2635	4,000
Hairy vetch, No. of farms		2	260
Acreage		12	?*
*(80,000 pounds of seed used).			
Dairy Feed Produced			
Oats	(Importing)		(Surplus for sale)
Corn, bu. improved seed used		14	1,200
Alfalfa, No. of farms	0	9	112
Acreages	0	150	300
Silos in county	1		129

Dairy Herd Improvement.

In 1914, butter and milk imported.

In 1923, county has 175 pure bred bulls, 1,500 pure bred cows, 2 creameries and 4 cream stations.

Beef Cattle Improvement.

In 1914, no pure bred cattle in county.

In 1923, county has 150 pure bred bulls and 650 pure bred cows.

Live Stock Disease Eradication.

In 1923, cattle ticks completely eradicated.

In 1918, tuberculosis eradication started.

In 1922, 0.5% reactors.

In 1923, no reactors.

COUNTY C.—A Typical Corn Belt County.

	In 1917	In 1923
Alfalfa grown, No. of farms	3	500
Acreage	22	2,000
Sweet clover grown, No. of farms	3	151
Acreage	28	5,510
Soybeans grown, No. of farms	15	1,500
Acreage	150	4,200
Limestone used, tons	500	4,000
Green manuring, No. of farms	?	125
Acres	300	13,000
Hessian fly control, No. of farms (1919)	50	(1922) 125
Acres	2,500	(1922) 10,000
Improved feeding in practice, farms	4	309
Poultry flocks culled	0	400
Modern poultry houses	0	120

COUNTY D.—A Typical Range County.

	In 1913	In 1923
Acres alfalfa grown	0	70,000
Acres sweet clover grown	0	70,000
Corn grown	0	3,500
Silos in use	0	30
Acres wheat sown with improved seed	0	25,000
Insect control, No. of farms	8	1,200
Acreage	100	150,000

In making this study, I confined myself to the teaching phases of extension work, as I feel that the fundamental duty of an extension worker is to teach. As stated clearly in the original Smith-Lever Act. "He should teach by means of demonstrations, established facts or practices to farmers and farm women on their farms." I recognize that there are other things that are perhaps necessary; but if the extension work is to succeed we must keep in mind the foundation upon which it is built.

In preparing these charts, I have endeavored to bring out that where the four fundamental steps (as outlined in the beginning of this paper) have been followed, the work has been reasonably successful. Very little of it has reached all of the farmers of any county; but we must keep in mind that there are only a limited number of the people who are ready and willing to accept new practices that are demonstrated for them, that the majority of the people are so constituted

that they will make changes slowly and do this more from imitating their more progressive neighbors than from following the teachings of the extension service directly. It is probably better that changes should take place slowly, for otherwise a stable agriculture might be endangered by too rapid modification of farm practices.

The figures I have given you have all been gathered from the view point of the extension worker, secured in most part from annual reports of county agricultural agents. During the past season two studies have been made which deal with this problem from the angle of the farmer and the farmer's wife, one in a county in a middle western state, where the extension work has been in progress six years, and one in a county in one of the eastern states, where the work has been in progress eight years. These studies have brought out the fact that of all the people interviewed seventy-one percent report that they were following some farm practice coming to them through the extension service, and when we include both the farm and home this figure is increased to seventy-eight percent. This indicates to me that the extension agents have been conservative in the figures I was able to get in preparing my own charts. Although we perhaps should assume that the counties studied were above the average, I believe that we are justified in feeling that, from the standpoint of both the extension worker and the farmer, the latter are following the practices demonstrated to them by the extension worker.

In closing I wish to express my belief regarding the value of the work of the scientist to the extension program. A study of my charts will show clearly the need of a more definite long-time program than many of the states have as yet developed. Such a program should take into account natural economic changes that must and will take place and should be one that, under normal conditions, would be reasonably sound for many years to come. Such a program will bring in new problems that must be solved, and in solving them the extension worker must look to the scientist. Perhaps many of these problems will not be pressing for years to come, and yet it is important when that time does come that they can turn to you for a definite solution for their vexing problems. I believe that extension work can never succeed as it should in any state without the hearty cooperation and assistance of the scientists at the colleges, the experiment stations, and the United States Department of Agriculture. Their work is the only foundation we have for a safe and conservative extension program.

4. THE COMPARATIVE VALUE OF FIELD DEMONSTRATIONS AND OTHER EXTENSION METHODS IN AGRONOMY[1]

H. R. SUMNER[2]

A very significant fact has been indicated when one-fourth of the program at the sixteenth annual meeting of this Society is devoted to a discussion of extension work in agronomy. This interest is the culmination of a gradual revolution in extension methods during the past few years. The methods have been changed and revised and improved until at present the extension project bids fair to supplant, to a certain extent, the old type of farmer's institute and extension school.

An extension project is a completely outlined program of extension work conducted throughout the entire year or a period of years. A successful extension program should be thorough and comprehensive. For example, if the project is one dealing with pure seed, then the campaign should include all the factors necessary in demonstrating the worth of pure seed.

In a well organized project the problem is outlined; the method of procedure illustrated; provision made for making the gained information available; and, finally, the number of farmers who have followed the recommended practice is ascertained. Such a program might be executed through the use of general meetings, farm visits, field demonstrations, subject matter or follow-up letters, demonstration reports, and general publicity.

As an extension worker understands the term, a project, in a certain sense, is an experiment designed to establish a fact which is well known to the extension workers, but not recognized as such by the farmer. Quite often the farmers are skeptical and, in their minds, the project is strictly experimental. The farmer must be convinced that the practice in question is the best one to follow. Therefore, the extension worker outlines the project with the express idea of proving the fact to the satisfaction of the farmer.

A project in bindweed eradication will illustrate this point. The bindweed is a serious pest in portions of Kansas. A bindweed eradication project has been outlined and a county-wide campaign has been inaugurated in several counties. The control methods are based upon several years of experimental work at the Fort Hays

[1]Paper read as a part of the symposium on "Extension Work in Agronomy" at the meeting of the Society held in Chicago, Ill., November 13, 1923.

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branch experiment station. The project is very simple. It is centered around a demonstration field which is placed in every community and on this field the farmer or demonstrator practices the necessary cultural methods. It is fairly certain that the weed can be eradicated if the directions are properly carried out; but it has never been done in this county before and hence, so far as the community is concerned, it is an experiment.

A field demonstration is a definite part, or unit, of an extension project. In this paper, a field demonstration will be considered in the light of its most recent interpretation and will be regarded as a single incident within the project. Any practical illustration of the value of a farm practice or of the methods employed in bringing about that practice is a field demonstration.

It is difficult to compare a strictly field demonstration and other types of extension work, because it is part only of a carefully planned project. In many cases it is merely incidental, and the chief point of attraction may be centered around a seed exchange day or an extensive auto tour. The field demonstration also may be used to create interest in the project or it may be utilized to summarize the year's results. But no matter how the field demonstration is used it is definitely interlaced with the other methods in the main project. That is the reason it is so difficult to compare the various methods used in extension work, they are all so dependent upon each other.

The field demonstration represents perhaps the most essential feature of effective extension methods. General subject matter meetings are necessary to a certain limited extent, during the winter months. Such meetings are used to inform the community of the project which is to be studied or of the results which have been secured in previous years. Personal or form letters dealing with the subject matter taken up at such meetings have been found to be rather effective substitutes for the general meetings. Such letters can be depended upon to hold the community interest. They, also, provide for the necessary follow-up, which is an absolutely essential element in any well organized project. Seed exchange days, auto tours, special truck exhibits, are all near relatives of the field demonstration. The field demonstration appears in many varied forms, depending upon the conditions under which the project is being conducted. However, it is easily the most effective extension method, for it teaches by means of the eye, by an actual performance record.

Nevertheless, a single field demonstration dealing with some subject which is not interwoven in an organized project fails to yield maximum returns. The community should be properly pre-

pared for the facts which are to be brought out in the demonstration. Later, an efficient follow-up is necessary in order to determine the number of farmers in the community who were benefited by the advised practice. The follow-up method also serves as an added incentive to those who hesitate to accept the new practice.

For example, a smut treating demonstration is held in western Kansas. It is a field demonstration of the various methods used in treating seed for smut. The audience is instructed in the means of treating seed for smut, but may not be convinced that smut is thereby exterminated. Hence, such a demonstration should at least be followed with an auto tour to several farms where the smut treatment has been used and contrasted with fields sown with non-treated seed.

Perhaps one of the greatest, as well as a most common fault with field demonstrations, is that those who are to be benefited are not given an opportunity to take an active part and so made to feel that it is their experiment. A worker who calls a farm meeting, tells something of the life history of smut, treats a peck sample of seed and then leaves with the parting admonition, "Do as I have done and you will have no more smut" is neglecting an opportunity.

Some very convincing field demonstrations were held in Montana two summers ago in connection with a campaign in favor of a home-made tillage implement and summer fallow. The farmers were called together by the county agent, who gave a ten-minute talk regarding the features to consider in choosing a machine suitable for their conditions. A dozen or fifteen farmers had brought their machines and immediately started operation in the field where the meeting had been held. For two hours the crowd followed and inspected the work of the implements. This demonstration was doubly effective, because it was done by the farmers themselves. A casual observer would have concluded that the demonstration was of the farmers' own volition.

This fall, in a northern Kansas county, a corn type and strain field day was held. It was a part of an organized corn improvement project started in the spring of 1923. Because of subject matter, letters, and other effective forms of publicity, all of the farmers in this county were aware of the fact that the farm bureau was making an effort to find the most desirable type and strain of corn. Fifty-two farmers were actively interested because their strains were under test, and many more were watching the work because it was their neighbors corn that was being tested. Still others were noticing the tests because seed from the local seed corn enthusiast, from whom

they frequently bought seed, was under trial. The plots were all harvested and yields determined by those who attended the meeting. It was a profitable meeting because: first, the demonstration was distinctly localized and of intense county interest; second, all understood what information they sought to obtain; and third, the farmers performed practically all of the work of the demonstration.

In that fashion the initial year of this project was summarized. The data secured will, of course, be further tabulated and reported through the local press.

The following outline further illustrates the relationship between the field demonstration and the other links in the project chain:

BINDWEED ERADICATION PROJECT

FIRST YEAR

1. The project is outlined before the county agent and his executive board.
2. Winter meetings. The demonstrators are selected at these meetings.
3. Follow-up or subject matter letters are sent to those interested.
4. Field demonstrations are held in the early spring.
5. Follow-up or subject matter letters are sent to the demonstrators.
6. Auto tour. A report is given by each demonstrator.
7. A report of the first year's results is presented at the annual farm bureau meeting, county fair or in the local press.

SECOND YEAR

1. A check is made on all who practiced control measures in the first year.
2. Extension methods are the same as for the first year.
3. All new demonstrators are given extra attention.

THIRD YEAR

1. The basis of two years local work is used to make the eradication campaign 100 percent effective.
2. General publicity work is given more attention.
3. Final report of project.

The types of demonstrations and the method of conducting extension work may, and necessarily must, vary considerably. Any one method without further reference to the other phases of the project is only half effective. A field demonstration is only half efficient if it is used without other support. However, by means of a well organized project, properly followed through, an agronomic extension program may be successfully completed.

5. THE EDUCATIONAL SERVICE OF OUTLYING EXPERIMENT FIELDS IN AGRONOMY[1]

F. C. BAUER[2]

An important feature of agricultural extension service is the dissemination of experiment station findings in such a manner as to encourage the adoption of them on the farms of the state as rapidly as conditions will warrant. A valued and widely used method in this service is the field, or farm, demonstration. Here, the farmer has an opportunity to see the results of the practice being recommended and to compare it with others not so useful or important. In the field of agronomy, and especially along the line of soils, there is more or less difficulty in carrying such projects to a successful conclusion. This is due primarily to the fact that those farm practices which deal with the soil and that are of lasting permanent value, cannot be demonstrated successfully in a single year's time. Such projects must be planned on a long-time program and confined to the same area of land.

Since the essential combinations for well planned demonstrations of this character are difficult to find, it becomes necessary to supplement them with existing material wherever possible. Such material may be found on the outlying experiment fields of the experiment station and on farms. Often times, however, that material which may be found on farms is more or less fragmentary and does not provide suitable contrasts to emphasize the lessons needed. The experiment fields, on the other hand, are well supplied with contrasted treatments and practices, and, in addition, they have the advantage of careful and exacting supervision, a condition which makes their results more reliable and the conclusions drawn from them more accurate. The chief disadvantage in the use of experiment fields for this purpose is their limited number and the consequent difficulty in applying specifically the lessons which they teach to a large territory. In spite of this difficulty, however, if the experiment fields are given the proper publicity thru demonstration meetings, and otherwise, they will serve to emphasize the fundamental farm practices and to point out to farmers specific problems which they should investigate for themselves. For this reason extension teaching in agronomy, and especially in soils, should make all possible use of outlying experiment

[1]Paper read as a part of the symposium on "Extension Work in Agronomy" at the meeting of the Society held in Chicago, Ill., November 13, 1923.

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fields. In Illinois, the outlying experiment fields have been used widely for this purpose and the discussion which follows will be limited entirely to this use of them.

Their Adaptability to Demonstration

During the course of its agronomic investigations the Illinois agricultural experiment station has conducted experiments on fifty-four outlying fields. These fields have been established in all sections of the state, on soils ranging from deep peat to dune sand. From time to time, it has been found necessary to discontinue some of them and occasionally new ones have been added. Thirty-eight of these fields are still in operation, three of them being devoted primarily to crop investigations and the others primarily to soil problems. Crop records are available for these fields over periods ranging from four to twenty-two years. Twelve distinct soil types, some in different glaciations or soil provinces, are represented on these fields. Nearly three quarters of them are located on three soil types which are representative of large soil regions in the state, namely, those representing the typical corn belt and the less productive regions in the southern third of the state.

The average outlying soil experiment field in Illinois contains about twenty acres of land, while the crop fields are about twice that size. The land on these fields is divided into series to correspond to the different fields upon a farm. Each series is sub-divided into smaller areas, usually fifth-acre plots, which receive different soil treatments in both livestock and grain systems of farming. Untreated plots are maintained as checks, in order to determine the effect of each soil treatment applied. On the fields now being operated, more than one hundred different treatments are used. Half-rod strips separate each plot and at least two rod strips separate one series from another, thus giving ample space to conduct the various operations necessary and for inspection. On many of the fields, there is also sufficient land available for systems of minor plots on which problems of special interest may be studied.

Crops are grown upon these fields in definite rotations. On some fields, two or more rotations are being tried. There are usually a sufficient number of series so that each crop in the main rotation at least, and often those of the minor rotation, may be represented each year. On the fields that are now being operated over the state, fourteen different crops are grown in thirty-nine rotation combinations.

Considering the outlying agronomy experiment fields from the standpoint of location, physical arrangement and the contrasts

that may be seen and compared on each individually and amongst each other, it appears that they should be well adapted for educational service among the farmers of the state. As an actual matter of fact, they have long been used to a greater or less extent for such purposes.

The Extent of Their Present Use in Demonstrations

Altho most of the outlying agronomy fields in Illinois were established before the advent of the farm bureau, most of them are in counties having such an organization. For the most part, farm advisors are active in creating a demand for the use of these fields for demonstration purposes, tho in some instances the interest of the farm adviser is somewhat negative. In the unorganized counties, the interest in the demonstrational value of these fields is somewhat less. This is due in part, no doubt, to a less effective publicity in these counties. In those sections of the state where soil problems are more or less acute, there is a large demand for demonstration meetings at the readily accessible fields. In other sections of the state, tho the demand is not so keen for such meetings, more or less interest can be created by planning and holding them and much good evidently comes from them. It has become the custom, therefore, for the University to devote some time each year to planning and holding timely demonstration meetings at various outlying fields when conditions are favorable for them.

These meetings are usually planned with one of three purposes in mind; namely to meet the local demand for opportunity to watch and study the field; to keep those in the natural environment of the field in touch with the progress being made; and to extend the results obtained and their importance to agriculture in general over a large territory.

Few plans are made for the local meetings. These are usually held when the University field man is at the field to harvest crops or look after other essential work and those in attendance are groups from the local community. Some times these groups may be a class of boys in vocational agriculture, or they may be a group of farmers whom the farm adviser has called together to study the results of a harvest being made, or the effect of winter and treatments on winter grain or legumes and other such problems. The groups of people at these meetings are usually small in number, but are greatly interested in the work.

The demonstration meetings held for those within the natural environment of the field are planned with more care. Usually an afternoon is devoted to such a meeting. Publicity is given the event

thru the farm bureau organizations concerned and in local newspapers. Such meetings are held at a field, either in the spring as early as the weather will permit, or during the summer and early fall. The spring meetings are usually devoted to a study of the sweet clover growing on the field to be used as a green manure for corn. The summer and fall meetings are devoted to an inspection of the crops growing at that time and a study of the general results obtained from the field. Because of the weather hazard, no special preparations are usually made on the field for the spring meeting. For the summer and fall meetings, exhibits of various sorts are often arranged to show graphically the results obtained upon the field along with the results from other fields somewhat similar in character, as well as exhibits to visualize some of the fundamental problems in soil improvement. These exhibits are studied more or less carefully by the farmers and have come to be regarded as an important part of many of these demonstrations. At these meetings, the farmers are given time to study the field and the exhibits with guides, after which they are assembled for a speaking program of one or more talks, in which emphasis is placed on the important lessons to be learned and in which an attempt is made to "drive home" the lessons desired. The farmers are always given opportunity for questions and discussion. Often times this part of the program has been one of the most valuable parts of the demonstration. This type of meeting constitutes the more common form of demonstration meetings at the outlying agronomy experiment fields.

During the past few years, from one to three all-day field demonstrations have been put on each season. This type of meeting is quite similar to the half-day meeting, except that it is planned on a larger scale. Instead of confining the demonstration entirely to soil problems, the problems of the farm as a whole are kept in mind. Such a demonstration calls for the cooperation of the various extension specialists. The result of it is the presentation to the farmer of a unified program on closely related farm activities.

The general plan for these meetings is to spend the morning at the field. As soon as the farmers arrive they are conducted about by competent guides. On this tour, they inspect the crops and study the differences between the differently treated plots; they inspect the numerous exhibits that have been arranged under the direction of various extension specialists for their study; they listen to the explanations which the guide makes of the things which they see and they enter into discussions amongst themselves and with the guide on the problems presented to them. After lunch, the visitors are assem-

bled in a comfortable place for the program, wihch occupies the fore part of the afternoon. At this time; the various extension specialists, and sometimes representatives of the various subject matter departments of the University, present and emphasize the essential features of their respective lines for that section of the state. Thus, the farmers have presented to them the important soil, crop, livestock, insect, horticultural and other problems characteristic of their section of the state. Sometimes, if the chief interests of the section in which the meeting is held is more or less specialized, more emphasis is put on these problems than on the complete program. Thus, in some of these demonstrations, the program has been confined to soils, dairying, and poultry. In others, horticulture has been included.

After the formal program, the visitors are allowed to separate into groups of their choice, for further demonstration and conference. Here they may take further opportunity to study the experiment field or they may watch a cow-judging demonstration, a poultry-culling or caponizing demonstration, or enter into conference with a specialist on the problems of more or less concern to them.

Altho such demonstrations are somewhat in the nature of a picnic or social gathering, the farmers are brought together for specific educational purposes. Their attention is focused directly on their agricultural problems. No outside forms of entertainment are allowed to interfere with the purpose of these meetings. No farmer can attend one of these meetings and not take away something that will be of value to him. Altho it requires some effort to plan and stage a demonstration meeting of this character, the returns appear to be justified and warrant a continuation of this type of meeting.

During the past three years one hundred and fourteen demonstration meetings have been held on the thirty-eight outlying soil and crop experiment fields in Illinois. This is at the rate of exactly one for each field each year. The actual distribution of these meetings is not, however, quite as regular as the above figures indicate. During the three years in question, there were four fields on which no demonstrations were held. There were three fields on which only one demonstration was held, eight fields with two demonstrations, nine fields with three demonstrations, eight fields with four demonstrations, two fields with five demonstrations, three fields with six demonstrations, and one field with eight demonstrations. It is thus apparent that some of these fields, for some reason or another, have not been utilized

extensively for demonstration purposes, while others of them have been used repeatedly.

Among the various factors explaining the variation in the use of the outlying experiment fields for demonstration may be mentioned accessibility, energetic farm advisers, the general attitude of the farmers, and the usability of the results obtained from the field. Of the four fields on which no demonstrations were held during the past three years, inaccessibility was a factor with two of them; while with the other two the lack of consistent results due to soil variations was chiefly responsible. The large number of demonstrations on some of the fields was due no doubt in large part to ambitious farm advisers and the favorable attitude of the farmers. In some instances, where there is little or no local interest in a field even tho it is yielding some very good results, good demonstrations have been held by inviting farmers from outside the immediate community to attend.

The attendance at demonstration meetings is more or less variable. The chief factors concerned here are the weather, the season, the interest of the farmer, and the type of meeting held. The local meetings, of course, are attended by only small groups. The half-day meetings are usually attended by numbers ranging from fifty to five hundred, and the all-day meetings by numbers ranging from five hundred to fifteen hundred. The meetings that are largely attended are usually made up of farmers from several counties. In one of the well-attended all-day meetings visitors were present from more than twenty counties. The weather and pressure of farm work are probably the most important factors in the matter of attendance.

The Effect of This Use on Their Efficiency in Investigation

Altho the outlying agronomy experiment fields have been used to considerable extent for demonstration purposes, they have never been used to such an extent that their efficiency in investigation has been impaired. No undue amount of time has been required from those who look after the details of the experimental work. The arrangement of the fields have made it easy to handle the visitors without interfering in any way with the various plots or the work going on. No doubt, a still greater use of these fields for demonstration purposes can be made without interfering with their investigational value.

On the other hand, the use of the experiment fields for demonstrations has probably been of a distinct value to them from the standpoint of investigation. At such meetings those in charge of the

investigations have been brought in close contact with farmers whose agronomic programs are in various stages of development. The questions, discussions, and experiences of the farmers, as brought out at the meetings, have been of considerable value in shaping and maintaining many practical aspects of the investigations. Thru such contacts with the farmer, the new problems of practical significance that are likely to arise from time to time will be more quickly and definitely emphasized. In general, it is more likely that the use of experiment fields for demonstration purposes will add to their investigational value as a whole rather than detract from it.

From this brief review of the Illinois agronomy experiment fields, it may be concluded that these fields, in general, are adapted to educational service thru demonstration and that such a use of them is not likely to impair their efficiency in investigation. The wide use of them for demonstration has made them exceedingly useful in extending agronomic information among the farmers of the state, and has undoubtedly contributed to some extent to their value as investigational fields.

6. OPPORTUNITIES FOR SELF-IMPROVEMENT WHICH SHOULD BE OFFERED THE AGRONOMY SPECIALIST[1]

E. L. WORTHEN[2]

The agronomy extension specialist occupies a comparatively newly established field, of which neither the boundaries nor the responsibilities have been definitely determined. In some instances, he is primarily an extension worker, well grounded in agronomy and giving first thought to agronomy subject matter in his extension activities. In other cases, he is first of all an agronomist who devotes the greater part of his time to extension teaching in his chosen field of subject-matter. Under the former condition, he would be looked upon first as an extension worker rather than an agronomist; while under the latter, as an agronomist specializing in a particular agronomic field. In either case, he would have more difficulty in keeping strictly up-to-date in subject-matter than either the research agronomist or the resident teacher. There certainly is, of necessity, a greater tendency for him to neglect subject-matter when not associated with his subject-matter department.

[1]Paper read as a part of the symposium on "Extension Work in Agronomy" at the meeting of the Society held in Chicago, Ill., November 13, 1923.
[2]Extension Professor of Agronomy, Cornell University, Ithaca, New York.

It will be my purpose to emphasize the dire need on the part of the agronomist doing extension teaching, of having the opportunity of self-improvement in his subject-matter. As a group of agronomy workers, we should appreciate keenly that those among us who are devoting their energies to extension activities are surrounded by much less favorable conditions for study than are those engaged in research or in resident teaching. The possible exception to this statement is the soil survey worker, who, like the extension teacher, is handicapped by his environment. It should be the concern of all to make more easily possible for those among us who are devoting a considerable proportion of time to outside work to keep up in subject-matter.

Prior to the passage of the Smith-Lever Act, the extension work of the agronomy departments was done jointly by those engaged in research and in resident teaching. In fact, the need of subject-matter specialists was not fully appreciated in the early development of our present extension organization. It was rather generally assumed that a county agent with a four-years college training in agriculture who, in addition, had practical farm experience, was adequately prepared to meet the needs of the agriculture of any individual county. The county agent was one of the first to recognize the need of subject-matter specialists. In the more progressive communities, the farmers themselves have been as prompt to demand the services of one who is especially trained and experienced in a particular line, to advise them relative to their various special problems. The administrators of extension activities have, in many instances, apparently lagged in their full appreciation of the need of a strong corps of subject-matter specialists in the building of an efficient and permanent extension program for a state and for the nation at large.

The agronomy extension specialist's field should be a broad one. He cannot and should not be simply a second-hand teacher of subject-matter furnished by the research or the resident teaching staffs. He must analyze the agricultural needs of the state and of the individual counties and develop comprehensive programs to meet their needs. He must have broad aims for the future agronomic development of the state. The specialist should not be the type of man who is willing to be a hired field assistant in extension service doing second-hand teaching for a subject-matter department.

If the extension agronomist is to measure up to the responsibilities of his job, he must first of all be a well-trained agronomist. While he must have a keen interest in the application of agronomic information and sympathy for the farmer's problems, he cannot neglect keeping

informed relative to the contributions which are constantly being made to the solution of our various soil and crop problems.

The extension teacher must obviously spend considerable time in the field, though by no means as much as some would have us believe. He necessarily concerns himself with the immediate problem at hand and, in meeting it, depends on the stock of working knowledge and his best judgment in applying it. Neglect on the part of the extension man to add constantly to his working supply of information would soon prove suicidal. New York farmers to-day would not be satisfied with an agronomy program based on the knowledge of ten years ago. Our agronomy extension teachers cannot long neglect subject-matter study; for, if they do, they will rapidly approach the old type institute workers in their methods, or as Director Christie well said at Washington last winter, "They may become assistants to the county agents."

Subject-matter is fully as essential to the extension agronomist as it is to the resident teacher or the investigator in agronomy. His responsibilities should be fully equal to those of his associates in the other phases of agronomy work. It is equally important that he be well prepared in fundamental agronomic information, thoroughly familiar with the more recent experimental data, experienced in teaching methods and fully capable of recommending adequate agronomic practices for the agriculture of his state. The research agronomist is primarily interested in securing new information, the resident teacher in instructing college students in the fundamentals of soil management and crop production and the extension agronomy specialist in applying the same subject-matter to the agricultural practices of the state.

Granting that the field of the agronomy specialist is a broad one and that the first requirement in measuring-up to the opportunity of this field is knowledge in subject-matter, then we are ready to give consideration to the problem as to how the extension teacher may be kept alert in subject-matter equally with the resident teacher and the research worker.

First of all, he must be associated most intimately with others interested in agronomy. The organization of the agronomy work should make provision for this relationship between all workers, whether in research, resident or extension teaching. This association must consist of more than an occasional conference between the various workers. The extension teacher in agronomy should feel that he is a part of his subject-matter department, functioning with the other members of that department. In short, he should be a

member of the department on equal footing with the resident teacher and the investigator. It is only under such environment that he can hope to find the most desirable conditions for self-improvement.

Simply providing a type of organization in which the specialist is associated with the other agronomy workers is not in itself sufficient to enable him to give adequate attention to his personal advancement in subject-matter. Spending, as he so often does, the larger proportion of his time in the field, counterbalances to a considerable extent the advantages gained by this type of organization. He should be an integral part of the department and given definite responsibilites along with the other departmental workers in determining policies and programs for the department. The extension agronomy program should have the benefit of the judgment of the resident teacher and the investigator. In the same way the resident teaching and research should be influenced by the practical problems encountered by the extension agronomist. It is not too much to expect that the extension specialist should participate, when not paid solely on Smith-Lever funds, in either resident teaching or the more practical type of experimental work or even in both. A reasonable amount of time devoted to either line of activity will do much to stimulate keen scientific interest in the recent developments made in agronomic problems. Any reasonable adjustment that may be made in organization so as to give the extension agronomist some responsibility in teaching or experimental work will go a long ways in encouraging him in self-improvement. Further some such inducement will have to be offered in order to secure and retain the services of sufficiently experienced agronomists to develop adequate state programs.

There are certain definite provisions which may be made to enable the extension worker to take advantage of the opportunities immediately at hand for his self-improvement. Chief among these may be mentioned: (a) he should be encouraged to attend and participate in departmental seminar; (b) he should have a voice in outlining policies in departmental conferences; (c) sabbatic leave or other periods for study or writing should be granted the extension agronomist on exactly the same basis with the other departmental workers; (d) he should be encouraged to belong to scientific societies and where possible financial aid should be given for his attendance at their meetings.

That agronomists engaged in extension teaching appreciate how essential it is for them to keep abreast of the times in subject-matter is evidenced by the following resolution passed unaminously by the

workers in the northeastern states at a conference held in Springfield, Mass., February, 1922:

"The specialist should apportion a considerable amount of his time to a study of the research work developed by his own station as well as other experimental institutions, even if this requires a curtailment of his efforts in other directions."

In short then, as agronomists, we must be interested in all phases of the subject—technical research, the more practical type of field experiments, and resident as well a extension teaching. The first requirement for an agronomist who devotes a considerable proportion of his time to extension teaching is that he function as a member of his subject-matter department. In addition, he should be on absolutely equal standing with his departmental co-workers in determining plans and policies of the department as a whole and should have equal opportunities with these assoctiaes for self-improvement in subject-matter.

7. THE SCIOTO COUNTY, OHIO, SOIL IMPROVEMENT PROGRAM, 1918-1923[1]

W. F. Gahm[2]

Having been raised on a farm in the adjoining county, Jackson, and having grappled with the soil problems there for many years, upon my arrival in Scioto County, Ohio, as county agricultural agent in February, 1918, I realized that a real problem confronted me in the way of a soil improvement program.

AGRICULTURAL CONDITIONS OF THE COUNTY

Topography

In Scioto County, there is marked diversity in surface features, with a range from fairly wide river valleys, with only a few feet change in elevation for several miles, to rough hills with steep slopes, rising quite precipitously to a height of 300 to 500 feet above the stream beds.

The southern portion of the county is bordered by the Ohio River for a distance of 40 miles. The central part of the county is crossed by the Scioto River flowing south. These river valleys range from one-half mile to two miles in width.

Beginning at the Ohio River near Wheelersburg, a point where the

[1]Paper read as a part of the symposium on "Extension Work in Agronomy" at the meeting of the Society held in Chicago, Ill., November 13, 1923.

[2]County Agent, Portsmouth, Ohio.

river flows almost due north, there extends thru the east central part of the county to the northeast a fairly level high plateau from one to three miles wide, known as the Kanauga River valley, which, in pre-glacial times, drained northward.

The rest of the county may be described as consisting of a succession of hills and sharply winding ridges, separated by deep, narrow valleys. In practically all of the county west of the Scioto River, the surface is sufficiently hilly to interfere very seriously with cultivation, and in fact, quite a large percenatge is so steep that cultivation ought not be attempted. The same is true of large areas just east of the Scioto River and again on the eastern border of the county. Part of the county consists of rounded hills, with many small, comparatively level areas well suited to general farming, but the topography of quite a large portion of the county is such as to make it best suited to pasture and forestry.

Soil Types

The soil of the hill land is largely Dekalb silt loam, which is acid, low in all plant food elements, notably phosphorus; but usually well drained and very responsive to good treatment.

The soil of the first bottom land is the Huntington silt loam, naturally very fertile, but sometimes slightly acid.

The soil of the second bottom land belongs to the Tyler and Holston series. The Tyler clay and clay loam have much the same characteristics as similar types of the DeKalb soils, except that they are poorly drained and not as responsive to good treatment. The Holston clay is better drained and its productivity is more readily improved.

Types of Agriculture

With such a diversity in surface features and soil types, it is only natural to expect a similar diversity in types of farming. These include general farming, orcharding, market gardening and livestock farming. The forest land (according to the 1920 census) amounts to 122,059 acres, which is more than is in forest in any other county in the state.

A study of the problem showed that little attention was given to the systematic improvement of the soil; that the yields of ordinary farm crops were low; that the carrying capacity of pasture land was far from being satisfactory; and that much of the land under cultivation was being badly eroded.

OUTLINING A SOIL PROGRAM

The situation was difficult but one which could be remedied by a well-planned soil improvement program. The first big problem was to

get the farmers to realize the seriousness of the situation; the second, to have them know the remedies; and the third, to get these remedies put into practice.

Statistics showed that less than 1,000 tons of limestone per year, and about 60 pounds of fertilizer per crop-acre per rotation were being used in the county. Only 2.6 percent of the cropped acres were growing legumes. Six acres of pasture land were needed for each unit of livestock kept.

The soil program, then, must be of such a nature as to bring about: first, the use of more limestone; second, the application of more fertilizer of the right kind; third, the introduction of better crop rotations including the growth of larger acreages of legumes; and fourth, the rejuvenation of permanent pastures. Along with this program naturally goes the better care of manure and the use of more tile on some types of soil, particularly in the Tyler clay.

1918

Realizing that demonstration is the most effective method of teaching, our first step was to arrange for fertilizer, limestone, and legume demonstrations in different sections of the county as quickly as possible. Following this, it was our plan to hold field meetings where results might be observed and discussed.

Believing that a knowledge of the facts as related to their own farms is one of the most effective means of getting farmers to realize their needs, in the spring of 1918 we asked seventy farmers to keep records of their farm business, in cooperation with R. F. Taber, farm management extension specialist. As a part of these records, there were some facts bearing on the fertility problem. While this method does not bring quick results, it is a means of gathering material that is valuable in formulating a long-time soil improvement program, fundamental to permanent agriculture.

In order to arouse interest and to get some rather definite results quickly, we began to hold meetings thruout the county discussing the situation and the soil problems involved, with special emphasis on the need of limestone and the use of more commercial fertilizer, with such brief mention of clover, particularly sweet clover, as would naturally come up in a limestone and fertilizer discussion. Our organization was crude at this early stage. We had only a township director who acted as chairman of all the extension activities in that township.

Ten such meetings were held, with J. F. Barker, soils extension specialist, present at the first six. Arrangements were made for twenty-two limestone and four fertilizer demonstrations, reaching

twelve of the sixteen townships. Considerable effort was made at these meetings, later followed up by some of the leading farmers, to encourage cooperation in the pooling of car-load orders for limestone and fertilizer. As a result more than 2,000 tons of limestone were used in 1918, an increase of more than 100 percent over any previous year. A similarly increased use of fertilizer was shown.

Since the prices of nitrogen and potash were extremely high at this time, special emphasis was necessarily placed on phosphoric acid. The following is an example of one of the demonstrations given county publicity:

James Appel applied 300 pounds of 16 percent phosphate per acre on his ten-acre plot entered in the Mens' Ten-Acre Corn Growing Contest. On this plot, corn had been the previous crop. On an adjoining ten-acre field, a clover sod was plowed down for corn. When it was time to judge the plot Mr. Appel was of the opinion that the corn on the unfertilized sod land would yield more than that on the fertilized plot. When the crop was husked and weighed it was found that the ten-acre fertilized plot yielded 1019.3 bushels while the same acreage of unfertilized sod land yielded a little less than 900 bushels.

Similar results came from the other fertilizer demonstrations and were given publicity thru newspaper articles, news letters and township meetings.

The following is an extract taken from the summary of our first year's farm management work:

CROP YIELDS

On level land where large areas can be handled by one man by the use of large machines and teams it is possible to produce crops so cheaply that money may be made even with low yields. On hilly land, however, where the growing of crops requires a larger amount of expensive man labor this is not true and it becomes absolutely necessary to fertilize and handle the land so as to grow as much as possible per acre.

Compare your Farm with the Average of 31 Farms and with Five of the Best

	Your farm	Average of 31 farms	Average of best 5 farms
Acres in crops		68	66
Value of all crops grown		$2775	$3394
Average value per crop acre		$ 41	$ 51

What do you learn from the comparison? Are you growing more per acre than the other men, or less? Fair market prices were taken in figuring the value of all farm crops so these figures represent true conditions.

The men in the group of the best 5 were producing over $600 worth more crops than the average of the 31 on practically the same acreage. How were they able to do so? They purchased $125.00 worth more of fertilizer last year than the average of the whole group. All but one of the best 5 men are regular users of limestone while but 43 per cent of the whole group use limestone. Likewise the men who secured the best crop yields keep more livestock than the average and so have more manure to use on the farm.

Let's get after this crop yield question, use limestone and fertilizer plentifully and wisely and increase our labor income thereby.

In the table under the heading "Your farm," each farmer's report had his own figures.

Numerous other comments on crop yields, as affected by the soil fertility practices of the different men, were contained in this report, which was given publicity thru the press and particularly in meetings where these summarized reports were analyzed, conclusions drawn and presented.

1919

Working with about the same type of organization, the only difference being that a few more men were interested in extension activities, we outlined our work for the year at a farm bureau directors' meeting.

It was planned, for 1919, to continue the soil program of the previous year. The need of more limestone and fertilizer and of growing of more legumes was to be given the greater part of our attention. Meetings were to be held, at which attention was to be called to demonstrations already started, and arrangements made for sweet clover demonstrations in connection with some of the limestone demonstrations started in 1918.

Meetings were held in twelve communities where the fertility program was discussed, with special emphasis on legumes, particularly sweet clover.

As a result of these meetings and numerous trips by the county agent, twelve sweet clover demonstrations were started, in eleven of the sixteen townships, aggregating 205 acres. Some others were started, but proved to be failures. These failures in most cases were due to the lack of limestone or of inoculation, for, in some instances, in spite of all that was said to the contrary, some men would sow sweet clover without correcting the acidity or without inoculating.

In some respects such failures proved to be demonstrations, inasmuch as they proved the fact that the "white-collared educators" really knew what the requirements are for the successful growing of these crops. We usually try to capitalize "failures" as well as successful demonstrations.

The following are extracts of newspaper reports on a few representative demonstrations:

> Dr. A. G. Stevens, at the suggestions of the soils specialist, sowed a 20-acre field of wheat to sweet clover on his Vernon Township farm. It was drilled in the early spring at the rate of 8 pounds per acre. The whole field had received a three-ton application of limestone at wheat seeding. One half of the field had received a two-ton application in a previous rotation.
>
> A good stand of sweet clover was secured on the entire field but the part receiving the two applications of limestone yielded more sweet clover hay.
>
> Dr. Stevens reports having harvested 42 two-horse wagonloads of sweet

clover hay this fall while his neighbors who used no limestone and sowed no sweet clover were clipping the rag weeds on their wheat stubble land. As to the quality of the hay and the question of livestock eating it, Mr. Perry, a tenant on the farm, says "The horses stop eating corn to enjoy the sweet clover hay."

This crop of sweet clover hay enabled Dr. Stevens to sell $500 worth of mixed timothy and clover hay, he otherwise would have had to feed.

As a further demonstration of the necessity of the presence of limestone in the soil, 6 acres of unlimed land adjoining the 20 acres were sown to sweet clover at the same time. It came up, grew but a few inches, then perished.

A similar demonstration may be seen on the farm of Otto Zoellner. Wheat was sown on corn land, the corn being cut up and shocked in a solid row. Two tons of limestone was applied preceding the seeding of wheat, the solid shock-row of corn, of course, received no lime. Sweet clover was drilled in the wheat last spring at the rate of 8 pounds per acre, drilling crosswise of the shock row. A good crop of sweet clover hay was cut this fall, approximately one ton per acre, but on the shock row, where no limestone was applied, a beautiful stand of wild grass may be seen and but seldom a stalk of sweet clover.

On the Bannon farm, in the rich Scioto bottoms, 20 acres of wheat were sown to sweet clover last spring and Mr. Charles Appel, superintendent of the farm says, "I harvested 40 tons of fine hay the latter part of August." Some complain of difficulty in curing, but Mr. Appel says, "This heavy crop was handled just as we always handle alfalfa with no more trouble in curing."

These sweet clover fields will be watched with interest and meetings held there next year.

According to our records, about 2,000 tons of limestone were used and fifteen more demonstrations started. It was said by many farmers that without doubt double this amount of limestone would have been used had it been more readily available. This condition led us to investigate the local sources of limestone, as will be seen further on in this report.

Splendid results were obtained from each of three fertilizer demonstrations on wheat, the following one of which will serve as an illustration: One-half of a twenty-five acre field of wheat on the Bannon farm was top dressed in the early spring with 200 pounds of 16 percent acid phosphate per acre on land that had received 150 pounds when seeded. The half receiving the additional 200 pounds yielded 4½ bushels per acre more than the other half. According to prevailing prices at that time $2.60 invested in fertilizer returned $9.67 in wheat.

This demonstration came as a direct result of one of our meetings where Mr. Barker had emphasized the desirability of using heavier applications of fertilizer than statistics indicated were being used in Scioto County. We have similar records on two other demonstrations. There is every reason to believe that our series of meetings resulted in many farmers increasing their rate of fertilizer application. Statistics show considerable increase in the tonnage of fertilizer used in 1919.

A demonstration in the use of fertilizer on corn, similar to that mentioned for 1918, was conducted by Charles Appel, in which he

applied 350 pounds of 16 percent acid phosphate per acre on the ten-acre plot which yielded enough corn to make him a member of the 100-bushel Corn Club of Ohio, while unfertilized check plots failed by 8 bushels to reach the coveted goal.

It has generally been thought that the soil of the Scioto bottoms is so productive that it would not respond to commercial fertilizers, but these experiences are causing many Scioto bottom land owners to begin the use of fertilizer.

The following is an extract taken from my annual report for 1919 showing the relationship of farm management records to the fertility project:

> Farm management records for this year showed that the best five farmers who kept records produced $56.00 worth of crops per acre, while the average farm produced $44.00. This was brought about thru better fertility practices as evidenced by the expenditure of $226.00 per farm for fertilizer and limestone on the best five farms, while the average farm received only $130.00 worth.
>
> The analysis of these records showed that the five best farms were growing more legumes. This was evidenced by an average nutritive ratio of 1:10 for the home grown feeds on these farms, and a nutritive ratio of 1:13 on the average farm.
>
> These figures support the argument in our soils project that money invested in limestone and phosphate fertilizer is a sound and profitable investment and is not what many farmers consider it, "A BIG EXPENSE."

A summarized account of the records was furnished to each man who kept a record. Meetings were held at which time these summaries were explained in detail, not only to those who kept records, but to all farmers who attended.

This summarized report was also made a part of the county fair exhibit.

1920

A slight change in the organized effort in soils work came, perhaps as a result of a new idea in the general plan of extension activities, namely, "The community plan," which was adopted in this county and started in four communities. This plan provided for a leader of each project in every community organized. It gave us the idea of appointing a soils chairman in each township. This was done, since this project was considered one of the most important and was reaching most of the county.

This was the beginning of what we hope will materialize into a real local "soils and crops" organization that will coordinate with a state organization beting fostered by the soils department of the Ohio State University at present represented in this section of the state by Mr. Earl E. Barnes.

Two years had now been spent in getting before the farmers the need of more limestone, fertilizer and legumes, and the starting of

numerous demonstrations. It was decided to check up the results, similar to those given above under results of 1919, as well as many others and to place them before the farmers in as vivid a manner as possible.

This was done by citing concrete results in meetings held for discussion of the project and thru news letters and newspaper publicity such as the following:

> Mr. Otto Zoellner of Wheelersburg has a ten acre field, one-half of which he limed at wheat seeding time in the fall of 1918 at the rate of 2 tons per acre. The limestone cost $3.00 per ton making a total cost of $30.00 for the 5 acres limed.
>
> In the fall of 1919, after wheat was harvested, 5 tons of red clover hay were secured by Mr. Zoellner from the five limed acres. During the summer of 1920, he cut 10 tons of clover hay, a total of 15 tons, from this area. On the 5 acres adjoining, he got nothing in the fall of 1919 and only 5 tons of hay during the summer of 1920. Therefore, he invested $30.00 in actual cash, which is responsible for the difference between 15 tons of good clover hay and 5 tons of fairly good mixed hay. The good effects of the limestone do not stop here, for it is only reasonable to expect larger yields on succeeding crops and it certainly shows the way to increasing fertility rather than to soil depletion.

Another means of getting results before the public was thru our county fair exhibit. A permanent farm bureau headquarters was erected, in which our exhibit was shown, the remaining space in the building being used as a rest room. The exhibit consisted of a combination of farm management and soils, featuring the "Value of Legumes" and the "Effects of Limestone."

Two miniature representations of farms on which records had been kept for two years were shown. Large card-boards and banners were used to show the exact feed value of crops grown on each farm. The exhibit showed how the well managed farm grew $560.00 worth more protein per year on 7½ acres less land than was used on the poor farm and how it was done thru the growing of more legumes, which was possible by the use of more limestone and fertilizer. The limestone exhibit was on the side of the booth near the best farm and connected with it by a red ribbon showing the relationship between the use of limestone and good legume crops.

The county agent was kept busy for two days estimating the limestone needs of soils, samples of which were brought there by farmers, and answering questions on the use of limestone and fertilizers.

Soy Bean Project

As a part of our legume program, fifteen soy bean demonstrations, aggregating 100 acres, were arranged for. As a result of this beginning the acreage of this crop has increased from a few acres at the time these demonstrations started to more than 2,000 in 1923.

Community Soil Demonstration Fields

Three community soils demonstration fields were established in accordance with the plan outlined by the soils department. This project is designed to demonstrate the effectiveness of logical, systematic fertility treatments followed thruout one or more rotations.

Samples of soil to be examined by Mr. George Valley, the soils extension chemist, were collected in the fall of 1920. After a laboratory examination, a system of soil treatment was worked out with the farm owner. This was designed to fit in, so far as practical, with the owners idea of crop rotation.

Field meetings are held on these fields each year, at which the practices being followed were discussed. After several rotations, the soils will be resampled and examined in the laboratory as a means of securing supplementary evidence of the effectiveness of the soil improvement system which has been used.

1921

Work was begun in fourteen communities, in each of which there was outlined a program of work in which some phase of soils work was incorporated. A project leader was selected by the people of the community and goals were set, stating the things which were to be done. These included such items as the use of 100 tons of limestone; the growing of 50 acres of soy beans; the holding of field meetings; the building of a limestone storage bin; and others; depending upon the community needs.

In order to familiarize these leaders with their job; to acquaint them with their fellow leaders in other communities; to get an idea from the soils extension specialist of how to proceed to get best results; a conference was held early in the year, at which eight of the fourteen leaders were present.

After considerable discussion of the various programs, the following resolution was passed:

> In order to encourage the use of more limestone three field meetings will be held on farms where there is outstanding evidence of the need of limestone as shown by the good growth of clover on limed land and the failure of clover on unlimed.

The places and dates of the meetings were decided upon and the project leaders each agreed to have a certain number of men present. These meetings were so arranged as to make it convenient for the several leaders to bring a few of their more progressive neighbors with them.

As was indicated in a previous statement, one of the difficulties in securing limestone is the lack of a convenient means of distribution.

A considerable amount of time was spent in securing samples for analysis of limestone from ledges in the north-eastern part of the county. Upon further investigation, it was found that the cost of quarrying, grinding and distribution would be too high to justify the investment necessary to develop the enterprise. The cooperative purchase of limestone then came up for consideration. Very few farmers were in position to buy limestone in carload lots. Accordingly, it seemed desirable to examine into the possibilities of a limestone storage-bin where limestone would be available at any time when the farmer happened to be in town with an empty wagon. Two communities decided to attempt the storage-bin plan.

The community demonstration project was discussed and the leaders voted that special effort be made to establish at least two more such fields, and if possible three, because it was thought necessary to have six such fields in the county in order to be representative of all soil types and agricultural conditions.

Field meetings were held as scheduled, the project leaders arranging for them and giving the necessary local publicity. Sixty farmers attended the meetings which was only two less than the goal set at the conference. These meetings, having been so well planned and attended, proved to us that the day spent in conference was well worth while. At each of these meetings, there was a discussion of the soil problems confronting Scioto County farmers and a consideration of plans for solving these problems. Attention was called to the community demonstration fields which were being established.

The plan for a storage-bin at Wheelersburg failed, in spite of a creditable effort on the part of the leader of that community. However, the Haverhill community succeeded in getting the stock subscribed; the land on which to build the bin leased from the railroad; and the application made for the charter.

The request for three more community demonstration fields was granted, all of which were established and soil samples taken during the fall of 1921.

Some effort was put forth by the soils leaders, in cooperation with the community purchasing agent, in the purchase of soybeans. As a result, 500 bushels of soybeans were bought in this way. This probably resulted in sowing that many beans more than would have been sown had no effort been put forth by the community leaders.

Farm Management Records

The year 1921 was the fourth one in which records have been kept in the county, by an average of 35 men per year. With a few exceptions the same men kept records each year.

For the year 1921, it was decided to work out a "Fertility Balance" covering the four-year period. A table, showing approximately the amounts of the plant food elements removed by various crops was used. Another table gave the comparison of the practices of the best five men with the average of the whole group, for the four years, as to whether or not the quantities of the essential soil elements were being maintained. In the reports sent to each man keeping a record was his own individual record, showing how he compared with the average of the whole group and with the average of the best five men.

The following are some of the figures and comments taken from the summarized report:

The report shows that the average farmer is returning 80 pounds of nitrogen, 197 pounds of phosphoric acid and 59 pounds of potash for each 100 pounds removed, while the best five show, for each 100 pounds removed, a return of 113, 309 and 75 pounds, respectively.

Apparently the average farmer in the county is maintaining his phosphoric acid supply fairly well, but, according to the analysis of the soil of the six community demonstration fields, he has a long way to go before reaching the point where it need not be of concern to him.

The nitrogen and potash supply is *not* being maintained by the average farmer. This is a problem, particularly as to the nitrogen, to which more thought must be given. Analysis of our soils show very low nitrogen content. They are fairly high in potash, but this is only available to an extent measured by the amount of organic matter present.

By comparing crop yields and labor income over the four year period, it is apparent that better methods of fertility maintenance pay.

CROP YIELDS AND INCOME
(4 YEAR PERIOD)

Average All Farms		Best Five Farms
Corn per acre	44 bu.	50 bu.
Wheat per acre	14 bu.	18 bu.
Labor income	$551.00	$1098.00

The next question is what methods do these best five men find most practical in maintaining fertility?

1. They use more lime.
2. They use more fertilizer. The average man spends $1.86 annually per crop acre for fertilizer while those among the best 5 average $3.12
3. They keep more stock, feed more of the crops on the farm and besides spend $452.00 annually more for feed than the average. This brings more plant food on the farm.
4. They grow more legumes, such as clover, soybeans and cowpeas.
5. They take better care of their manure, keep it hauled out and don't allow the plant food to leach out of it in the barn lot or in a pile against the barn.

Good soil fertility practices are a very important part of profitable farm management and the farmer who ignores any of these means of increasing the productivity of his farm is thereby decreasing the future earnings of his business.

This report unquestionably had the "evangelistic" effect in stimulating interest in our soils program in every community in the county.

In our community program-planning meetings, where community analyses were made, this material was used. Without exception, this report influenced the committee to include more soils work in their

program. The answer was "fertilizer and limestone schools," a project offered by the soils department.

1922

The community soils leaders were selected for this year at the community program-planning meetings, with the understanding that they are to be permanent leaders in their communities. As far as possible, in communities where demonstration fields are established, the owner of such a field was made the soils project leader.

The leaders met in conference, in February, for a discussion of the county soils problems. The analysis of the soils of the six demonstration fields and the farm management data on fertility maintenance served as a basis for discussion. General policies were outlined, arrangements were made for conducting a number of "limestone schools," and a new phase of fertility work was presented, namely, "pasture improvement." The committee readily agreed as to the need of pasture rejuvenation. The final decision was that a few demonstrations should be started in the spring of 1922 as a forerunner to a more strenuous campaign for 1923.

Six fertilizer and limestone schools were held, where numerous limestone-requirements determinations were made. The "Ohio Standard Dozen" fertilizer analyses were discussed and the increased use of better fertilizer was urged.

Five pasture-improvement demonstrations with a limestone and phosphate treatment were started and field meetings were held the day that the treatment was given, with a total attendance of forty-six.

The county agent and the soils extension specialist had nothing to do with this work from the time the conference was held in February, until the treatment was given in May, at which time both were present to discuss just what may be expected of such treatment and to map the fields as to treated and untreated plots.

We believe that the success of this project was due largely to the fact that the project leaders had been convinced of the importance of the work; they knew what they were expected to do; and had planned the method of doing it. The planning had been done at the project-leaders conference, which we expect to repeat annually.

Following the plan of the previous year in regard to encouraging the growing of soybeans, the soils leaders cooperated with the local purchasing agents in pooling orders for beans, as a result of which 800 bushels of seed were purchased, all from outside the county. Very little seed was grown, except in a small way by a few men for their own use. In driving thru the county, the increased number of soybean fields is very noticeable.

In February, 1921, arrangements were made with the County's only paper, a daily having a circulation of 15,000, for all the space desired in the Saturday issue, under the heading of "Agricultural Notes," the material for which was to be prepared by the county agent. Numerous timely articles were published in the "Agricultural Notes" column, pertaining to the feeding value of soybeans; their effect on fertility; the results obtained by local growers and their experiences in growing them. These had something to do with their increased use, as was evident from the fact that many times farmers, in talking with the county agent, referred to the article read in the "Times."

Fertilizer demonstrations on tomatoes and potatoes were begun during the year, in which the effectiveness of a 4-10-4 analysis was made very apparent by the increases in yields. In one case, for example, the value of the increase above the cost of the fertilizer from an application of 800 pounds of fertilizer of this analysis amounted to $63.89 per acre. A 4-10-4 fertilizer applied at the rate of 1,000 pounds per acre on potatoes also gave profitable returns, the increase in yield ranging from 36 to 90 bushels per acre. Publicity was given these results thru the press, at farm bureau meetings, grange meetings and farmers' institutes.

The following is an extract from the 1922 summarized farm management report pertaining to our fertility problem:

ARE OUR FARMS BECOMING RICHER OR POORER?

This is a question which is often asked and which the following table based on the farm records for 1922 answers.

The Percentage of the Nitrogen, Phosphoric Acid And Potash Removed from the Soil by Crops which is Returned Through Manure and Fertilizer.

	Your farm	Average all farms, 1922	Best five farms, 1922
Nitrogen		89%	107%
Phosphoric acid		174%	204%
Potash		66%	84%

Compare your farm with the average and with the best paying farms. The best paying farms are building up the supply of crop growing elements in their soils while the average farm is being depleted of these elements, particularly nitrogen. The most practical methods of building up the nitrogen supply are:

1. To conserve the manure. Of the five better paying farms two have covered barn yards, one hauls all manure directly to the field and the other two haul all manure to the field as made except that around the straw stack.

2. To add to the nitrogen supply thru the use of legumes. All farms were divided into two equal groups according to the percentage of crop land in legumes in 1922. The following table tells the story.

	Crop land in legumes	Yield wheat per acre	Yield corn per acre
Farms with least legumes	13%	12 bu.	30 bu
Farms with most legumes	24%	14 bu.	45 bu.

1923

On January 23rd, the soils leaders met at the regular annual soils conference, at which time a County soils program was outlined, based on the community programs. In this conference two projects were considered in detail, viz., "pasture improvement "and "fertilizer and limestone schools."

After going over very carefully the requirements for the pasture improvement demonstrations, a plan was outlined showing the part which the soils leaders, county agent and soils extension specialist each should take, in order to make the project a success thruout the entire county. These were as follows: Each soils leader was to secure one or more demonstrators and to submit a sample of the soil of the proposed demonstration fields to the county agent not later than March 15th. The agent was to forward these sample to the soils department; where lime-requirement determinations were to be made and the results reported ten days after the samples were submitted. The demonstrator was to treat at least one acre of land with sufficient limestone to satisfy the lime-requirement and at least 400 pounds of 16 percent acid phosphate or its equivalent in some other carrier of phosphorus.

In connection with this project, it was decided that the week of June 11th was to be known as "pasture improvement week," at which time a series of meetings was to be held for the purpose of discussing the results of the many demonstrations in this section of the state which are now showing notable improvement as a result of treatments during the previous two years.

At these meetings, there was a discussion of the reasons for the "Ohio Standard Dozen" fertilizers. The leaders were urged to make every effort to get their respective farmer friends to report at the "fertilizer and limestone schools."

The limestone storage bin again came up for its share of discussion, after a report was heard from Haverhill Community that the bin in that community had been erected but was not yet in operation because of some difficulty in the installation of machinery. It was the opinion of all those present that the storage-bin idea was sound and that it was the best known means of having limestone available at all times, this being a very important factor in a limestone program.

Further investigation was to be made by all the leaders of the desirability of installing other limestone bins in other localities.

As a result of the work of this committee, thirteen "pasture improvement" demonstrations were started in seven communities on a total area of about 75 acres. Six other pasture demonstrations were arranged for in three other communities, but up to date these have not received limestone. "Pasture improvement week" was observed beginning June 11th as planned. Considerable advance advertisement was given to the project by means of posters and newspaper publicity under the slogan "Make Scioto County White." During the week preceding the meetings, "With White Clover" was added to the slogan. The first posters and newspaper publicity under the slogan "Make Scioto County White" created considerable comment and aroused interest as the following incident indicates. Only one reporter on the daily paper had all the information pertaining to the slogans and it was thru him that all the newspaper publicity was being given. One morning another reporter, running into the office excited and almost breathless, was heard to exclaim, "My God! the Ku Klux Klan are working fast in this county, they are getting ready to run out all the negroes!" "Surely not!" exclaimed the knowing reporter. "Yes! A bunch of fellows up the street told me they had posters up all over the county, "Make Scioto County White."

The following is one of the many press articles announcing the meetings:

"WITH WHITE CLOVER"

This is the addition to the slogan chosen by the Soil Committee of the Farm Bureau, making it read "Make Scioto County White with White Clover," meaning that the luxuriant growth of white clover is the basis of good permanent pastures.

Mr. Barnes, Soils Specialist, Ohio State University, will discuss in detail the most economical methods of pasture improvement at the meetings to be held throughout the county next week. Soil testing for lime-requirement will be a feature of every meeting. Any farmer desiring to know how much limestone he should apply on any or all fields can find out without cost by bringing a sample of soil to any one of the meetings to be held at Haverhill, Empire, Minford, Lucasville, Sedan, Otway and Ohio Valley.

Another press article reported results of a meeting as follows:

Five hundred farmers and their families heard Mr. E. E. Barnes, Soils Extension Specialist, Ohio State University, in a series of meetings closed yesterday at Ohio Valley Grange Hall.

"Scioto County can and should be made white with white clover within the next five years" said Mr. Barnes. In pointing out the economical way of doing so, he said in part "Every farmer would be happy if he had a good bluegrass sod on his permanent pasture land. To get them, two things must be done—the lime-requirement met and nitrogen added. To meet the lime requirement, test the soil and apply limestone to meet the requirement. Apply phosphorus in the form of acid phosphate or basic slag. This stimulates the white clover which, by its luxuriant growth, supplies the nitrogen necessary for good bluegrass. Usually the second or third year the bluegrass begins to crowd out the white clover.

Where there was any trace of tame grasses and a few white clover plants could be found in a field to be treated, the recommendations were—limestone to meet the lime-requirement and 400 pounds of 16 percent phosphate, or its equivalent, per acre both applied as a top dressing, with no cultivation and the sowing of no seed. It was suggested that the application of limestone might be made at any time of the year except that on steep hillsides it should not be done when the ground was frozen. The danger in such a case being that a heavy rain might fall before thawing occurred which would result in the material washing away. It was pointed out that the results might not be noticeable until the second year after the treatment was made, altho in a favorable season it might be seen the first year.

Where there was absolutely no tame grass or clover the advice was to make a light seeding of alsike clover, Japan clover, timothy and red top, following a good disking of the ground, but certainly no plowing on hillsides where there was danger of erosion.

That farmers are interested in the pasture improvement project is shown by the fact that more than 500 of them in south-eastern Ohio are treating one or more acres of pasture land according to the above recommendations. This number includes 14 in Scioto County who have treated or will do so this summer or fall. They are, according to reports of the community Soils Chairman on file at the County Agent's office,—Ray Freeman, Otway; Wilbur McJunkin and O. F. Dodds, Sedan; L. H. Marsh and E. C. Moulton, Lucasville; David Bennett, Thomas H. Bennett and L. B. Poole, Minford; Fred Lang, Wheelersburg; John D. Oakes and Jacob Hammerstein, Empire; and Wm. Brush, Frank Oakes and Frank Boynton, Haverhill. There may be others, and if so it is requested by the soils chairman that reports be made to them or to the County Agent. The fields treated the spring of 1922 were inspected during the summer by a fairly good sized band of tourists, where it was easily possible for anyone to point out the treated plots."

The following article appeared in the "Agricultural Notes" column under date of September 29th:

HAVERHILL LIME COMPANY BUSY

The Haverhill Limestone Company is doing a splendid business, according to Smith Graff who has charge of the distribution.

Mr. Graff says, "Since about the first of May, 250 tons of limestone has gone thru our storage bin, which is certainly several times what would have been used had farmers depended on the usual way of securing it in carload lots."

Among those who have secured limestone thru the bin are, Frank Boynton, Wm.Brush, Charles Brush, A. S. Goddard, Chris Schilling, Henry Groh, Ora Smith, George Selby, Thomas Lavender, S. M. Varney, Frank Oakes, and S. E. Crickenberger.

Henry Groh hauling with truck for his father and Ora Smith says, "He would rather haul from Haverhill storage bin with the convenience and services rendered, than to haul from car at Wheelersburg, which is several miles shorter haul."

SUMMARY

1. An organization of community soils leaders has been effected. These leaders meet annually to consider problems and methods of solving them.

2. There has been a notable increase in use of limestone and fertilizer as a result of demonstrations.

3. The legume acreage, particularly that of sweet clover and soybeans, have been very considerably increased.

4. Numerous successful pasture rejuvenation demonstrations have been begun.

5. Six permanent community demonstration fields are in operation.

6. A supply of limestone, available at all times, has been made possible in one community by the building of a storage bin.

FUTURE PLANS FOR SOILS PROGRAM IN SCIOTO COUNTY

1. *Continuation of pasture demonstration.*

It is planned to organize "pasture improvement" clubs in those communities where the small plot demonstrations have been in progress long enough to have convinced a considerable number of men that it is a workable plan. The plan is to enlist men in the project who will treat five acres a year for a period of five years. These men will meet at least yearly for a tour of interesting demonstrations on pastures and will make a special study of the pasture problem.

Another new phase of pasture improvement work will be started this year which is designed to show the effect of the limestone-acid phosphate program on the gains made by livestock. One of these is already arranged for. A thirty-acre field has been selected. Ten acres will be treated and separated from the rest by a fence. The department of animal husbandry is ccoperating in checking up on the amount and economy of gain on the two herds.

2. *Alfalfa demonstrations.*

Knowing that on a livestock farm there was a need for more legume hay than is commonly produced, it is felt that it is desirable to demonstrate in each community the possibility of establishing and maintaining a field of alfalfa of five acres or more. Starting in the spring of 1923, one of these will be established in each community. A year is to be given to preparation. The first year, sweet clover will be sown and enough limestone will be supplied to make it a success. The next year, it will be plowed and kept in fallow until seeding time. It will be the object to keep these fields in this crop as long as possible. To do this, they will be fertilized and harrowed regularly each year. Field meetings will be held on these fields as fast as they become of demonstrational value and thereafter whenever there is anything of interest to be shown.

3. *Fertilizer and limestone schools.*

Following the plan of the past two years, fertilizer and limestone schools will be held in a number of communities during the coming winter months. At these the advantages of high-analysis fertilizers will be stressed and farmers will be instructed in methods of comparing values of different brands.

Samples of soil brought in by farmers will be examined for their

lime-requirement. At these meetings, the building of limestone storage bins will be encouraged and any community showing an interest in this method of securing a constant supply of limestone will be given additional help in the matter of determining the best type of organization. Thru cooperation with the agricultural engineering department, we will also be able to give them helpful hints as to the best type of bin to build.

4. *Community Soil Demonstration Fields.*

The six fields established in previous years, where up-to-date methods of soil management from all angles are being shown on the same field, will be continued. Field meetings will be arranged on as many of these during the coming year as seems advisable after the crops are started. Data from these fields will be discussed at the fertilizer and limestone schools during the following winter.

AGRONOMIC AFFAIRS

THE COLORADO PURE SEED SHOW

The Annual Colorado Pure Seed Show was held in Colorado Springs on November 13–16, 1923. There were presented at the show pure seeds eligible to certification and registry of a total value estimated at nearly $200,000, exhibited by growers. Buyers are beginning to make use of this opportunity to purchase seed stocks; both seed houses and individual purchasers being represented at the show. In the opinion of the agronomists of the State College, this show has been a very influential factor in promoting the whole program of improved crops through improved and certified seed.

SOYBEAN HARVESTER SAVES LABOR

A row soybean harvester which beats the beans from the standing stalks when thoroughly dry and is operated by two horses and one man has been a factor in the soybean work of County Agent E. V. Breeden, Orange County, Va. This is a dairy county, using a large amount of concentrates and legume hay. Mr. Breeden selected soy beans as a promising crop to meet this need and one which could be profitably grown there.

He secured in 1922 the purchase of two of these seed harvesters which he personally knew to be satisfactory, after a number of demonstrators had planted sufficient acreage of soy beans for seed to make the use of the harvesters worth while. That year over 2,000 bushels of seed were harvested from perhaps 15 farms. This year 12 harvesters were run, harvesting on 36 farms. More than 800 acres were grown for seed, 200 acres of which were entered for certification.

As home production of seed increases the plowing under of a part of the crop as green manure will be increasingly stressed.

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SULFUR IN RAINFALL IN KENTUCKY[1]

E. M. JOHNSON[2]

Improved methods of analysis have shown that plants require much more sulfur than was found by the old method of analyzing the ash. With this knowledge came investigations of the sulfur problem in agriculture in all its phases. Much work has been done in determining the sulfur content of the rainfall. Wilson (10)[3] and Erdman (2) in recent publications, gave rather extensive reviews of the literature on this subject. The results obtained by the various

TABLE 1. *Sulfur in rainfall.*

Place of collection	Investigator	Period	Average annual rainfall	Pounds elemental sulfur per acre per year
Rothamsted, Eng.	Miller (4)	1881–'87	29.95	6.97
Lincoln, N. Z.	Gray (4)	1884–'88	29.70	5.98
Catania, Sicily	Sestini (4)	1888–'89	18.36	8.37
Garforth, Eng.	Crowther (1)	1906–'09	26.95	38.32
Leeds, Eng.	" (1)	1907–'08	27.10	64.58
Urbana, Ill.	Stewart (7)	1913–'19	——	45.10
Mt. Vernon, Ia.	Peck (6)	1916–'17	17.69	3.38
Mt. Vernon, Ia.	Trieschmann (8)	1918–'19		.61
Ithaca, N. Y.	Wilson (9)	1918–'23	28.50	29.50
Pullman, Wash.	Olson & St. John (5)	1920–'21	22.00	5.57
Knoxville, Tenn.	MacIntire & Young (3)	1913–'21[a]	50.42	51.50
		1915–'21[b]	48.44	94.50
		1919–'20[c]	58.14	18.60
Ames, Iowa	Erdman (2)	1921–	30.38	14.89

[a]University Farm [b]Weather Bureau [c]Ogden Farm

[1]This paper is part of a thesis presented to the faculty of the College of Agriculture, University of Kentucky, in partial fulfilment of the requirements for the degree of Master of Science in Agriculture. The work was done under a fellowship provided by the Gypsum Industries Company. Received for publication February 20, 1924.

[2]Assistant in Agronomy, University of Kentucky, Lexington, Ky.

[3]Reference by number is to "Literature Cited," p. 355.

investigators both in this country and abroad are widely different, as may be seen from the summary presented in Table 1.

EXPERIMENTAL WORK

Rainfall was collected and analyzed for sulfur content from seven gauges located in six localities in Kentucky. The location of the gauges with reference to cities and railroads is indicated in Table 2.

TABLE 2.—*Location of gauges from which rainfall was collected.*

Place of collection	Nearness to railroad	Nearness to city.
Lexington (U. S. Weather Bureau)	1 city block	Heart of city.
Lexington (Van Meter farm)	1½ miles	1½ miles from Lexington
Lincoln Institute	¾ "	8 miles from Shelbyville, population 4,000.
Paducah (Lone Oak)	4 "	4 miles from Paducah, population 25,000
Mayfield	½ "	1½ miles from city of 6,500.
Russellville	¼ "	¼ miles from city of 3,000.
Greenville	¼ "	2 miles from city of 2,000.

The standard United States Weather Bureau eight-inch gauge was used for the collection of the rainfall. After each rainfall, the collector poured the water into a glass carboy provided for the purpose. To prevent the loss of sulfur by bacterial action, 25cc. of bichloride of mercury solution (1 to 1000) were placed in each container. The rainfall was analyzed by periods of three months each. Collection was started on April 1, 1921, and continued until April 1, 1923. The periods were so arranged that analyses could be made in both the winter and summer months.

In Table 3, there is shown the average sulfur content of the rainfall for the two-year period for the seven stations. The amount

TABLE 3.—*Sulfur in rainfall in Kentucky (1921 and 1922).*

Place of collection	Average annual rainfall	Average annual precipitation of sulfur, pounds per acre	Pounds of sulfur per acre-inch of rainfall
Lexington (U. S. Weath. Bu.)	44.90	41.19	.94
Lexington (Van Meter farm)	45.60	23.84	.52
Lincoln Institute	41.37	17.10	.41
Paducah (Lone Oak)	42.80	33.86	.79
Mayfield	49.62	25.92	.52
Russellville	43.56	29.80	.68
Greenville	45.54	35.97	.79
Average	44.77	29.52	

of sulfur carried to the soil by rains as an average of the state as computed from the data shown in Table 3 is 30 pounds per acre per year. This average does not include the amount of sulfur in the rainfall collected at the Fayette National Bank building for the winter period, nor the data for January, February, and March, 1922,

for Greenville and Russellville. The Lexington data were not included because the gauge was placed near the smokestack of the building and during the winter the rainfall contained a large amount of soot. The Greenville and Russellville rainfall for the period noted was contaminated with sediment of an organic nature and ran very high in sulfur. Inclusive of these data the average for the state is about 36 pounds of sulfur per acre per year.

In order to show the seasonal variation of the sulfur content of the rainfall, the average quarterly precipitation of sulfur is given in Table 4. These figures are average of the data from the seven gauges:

TABLE 4.—*Quarterly precipitation of sulfur in rainfall in Kentucky.* (Average of seven gauges for two years)

Quarter	Months	Pounds of sulfur per acre per quarter	Rainfall per quarter	Pounds of sulfur per acre-inch of rainfall
1	January, February, March	13.330	14.88	.89
2	April, May, June	7.087	9.45	.75
3	July, August, September	6.355	9.52	.63
4	October, November, December	9.337	11.63	.80

The results indicate that the sulfur content of the rainfall is greater in the winter than in the summer.

The location of the gauge with reference to railroads and cities affects the sulfur content of the rainfall.

Yearly estimates of sulfur in rainfall based on analyses of a few collections are inaccurate, because the sulfur content of the rainfall is variable.

LITERATURE CITED

1. CROWTHER, CHARLES, and RUSGTON, A. G. The nature, distribution and effects upon vegetation of atmospheric impurities in and near industrial towns. *In* Jour. Agr. Sci. 4:25–55. 1911.
2. ERDMAN, L. W. Sulfur in rainfall. *In* Soil Sci. 14:363–367. 1921.
3. MACINTIRE, W. H., and YOUNG, J. B. Sulfur, calcium and magnesium content and reaction of rainfall at different points in Tennessee. *In* Soil Sci. 15:205–227. 1922.
4. MILLER, N. H. J. The amounts of nitrogen as ammonia and as nitric acid and of chlorine in the rain water collected at Rothamsted. *In* Jour. Agr. Sci. 1:280. 1905.
5. OLSON, GEORGE A., and ST. JOHN, J. L. An investigation of sulfur as a plant food. Wash. Agr. Exp. Sta. Bul. 165. 1921.
6. PECK, E. L. Nitrogen, chlorine and sulfates in rain and snow. *In* Chem. News, 116:283. 1917.
7. STEWART, ROBERT. Sulfur in relation to soil fertility. Ill. Exp. Sta. Bul. 227. 1920.

8. TRIESCHMANN, J. E. Nitrogen and other compounds in rain and snow. *In* Chem. News, 119:49. 1919.
9. WILSON, B. D. The quantity of sulfur in rain water. *In* Jour. Amer. Soc. Agron. 15:453–456. 1923.
10. WILSON, B. D. Sulfur supplied to the soil in rainfall. *In* Jour. Amer. Soc. Agron. 13:226–229. 1921.

NITROGEN IN THE RAINWATER AT DIFFERENT POINTS IN KENTUCKY[1]

J. F. FREEMAN[2]

Considerable work has been done in determining the amount of nitrogen in the precipitation in various parts of the world. Wilson (3)[3] of Cornell University has reviewed quite fully the literature on this subject.

Since collections of rainfall were being made at various points in Kentucky for the determination of sulfur,[4] it was thought advisable at the same time to determine the amounts of nitrogen present. The location of the gauges used in collecting the rainwater with reference to railroads and cities is described in the preceding article.

At Russellville, Greenville, Mayfield and Lone Oak, the gauges were set up at the edge of the farmyard, near the stables and usually not more than 50 ft. from the residence of the caretaker. At Lincoln Institute and Lexington (Van Meter Farm) the gauges were located in open fields.

The rainfall was analyzed by periods of three months each. Results were obtained for five periods, beginning January 1, 1922, and continuing thru April 30, 1923. The results for the Lexington (Fayette National Bank) location are not included in Tables 2 and 3. The rainwater of certain of the fields for the first period contained considerable foreign matter of an organic nature. For this reason, only the results of the last four periods are used in determining the annual results.

The Nessler reaction employed in water analysis, as outlined by Olsen (2), was used in determining the ammonia nitrogen.

The nitrate nitrogen was determined by the phenoldisulfonic acid method. One hundred cc. aliquots of the rainwater were evaporated to dryness on the hot water bath in the presence of a small amount

[1]Contribution from the Department of Agronomy, University of Kentucky, Lexington, Ky. Received for publication April 4, 1924.
[2]Superintendent of Experimental Fields.
[3]Reference by number is to "Literature Cited," p. 358.
[4]See preceding article.

of base, the residue treated with phenoldisulfonic acid solution prepared according to Chamot, Pratt, and Redfield (1) and the customary procedure followed, bringing up to volume with cold distilled water, developing color with ammonium hydroxide solution and comparing with standard nitrate solution in Schreiner colorimeter.

TABLE 1.—*Nitrogen in rainwater.*

Location and Period	Rainfall inches	Ammonia N per acre lbs.	Nitrate N per acre lbs.	Total N per acre lbs.
At Russellville, Kentucky				
Jan., Feb., Mar., 1922.....	15.33	1.54	1.61	3.15
Apr., May, June..........	10.34	8.62	.96	9.58
July, Aug., Sept..........	6.25	3.62	.19	3.81
Oct., Nov., Dec..........	5.64	.49	1.28	1.77
Jan., Feb., Mar., 1923.....	20.13	1.28	1.14	2.42
Totals for last four periods.	42.36	14.01	3.57	17.58
At Greenville, Kentucky				
Jan., Feb., Mar., 1922.....	12.54	6.02	2.36	8.38
Apr., May, June..........	15.29	4.86	1.48	6.34
July, Aug., Sept..........	8.89	6.75	4.02	10.77
Oct., Nov., Dec..........	11.82	1.72	2.68	4.40
Jan., Feb., Mar., 1923.....	17.23	1.59	1.48	3.07
Totals for last four periods.	53.23	14.92	9.66	24.58
At Mayfield, Kentucky				
Jan., Feb., Mar., 1922.....	13.05	0.87	5.09	5.96
Apr., May, June..........	11.78	2.73	.71	3.44
July, Aug., Sept..........	7.47	2.32	3.12	5.44
Oct., Nov., Dec..........	13.00	.89	4.57	5.46
Jan. Feb., Mar., 1923.....	17.65	.72	1.52	2.24
Totals for last four periods.	49.91	6.66	9.92	16.58
At Lone Oak, Kentucky				
Jan., Feb., Mar., 1922.....	14.65	1.49	1.28	2.77
Apr., May, June..........	9.22	1.02	.71	1.73
July, Aug., Sept..........	5.20	4.65	2.07	6.72
Oct., Nov., Dec..........	6.82	.74	1.60	2.34
Jan., Feb., Mar., 1923.....	16.46	1.42	1.99	3.41
Totals for last four periods.	37.70	7.83	6.37	14.20
At Lincoln Ridge, Kentucky				
Jan., Feb., Mar., 1922.....	10.30	1.08	4.38	5.46
Apr., May, June..........	9.50	1.72	.68	2.40
July, Aug., Sept..........	6.18	2.46	2.73	5.19
Oct., Nov., Dec..........	9.30	4.24	2.17	6.41
Jan., Feb., Mar., 1923.....	3.75	2.18	.94	3.12
Totals for last four periods.	28.73	10.60	6.52	17.12
At Van Meter Farm, Lexington, Kentucky				
Jan., Feb., Mar., 1922.....	12.91	.92	4.06	4.98
Apr., May, June..........	10.26	1.89	1.76	3.65
July, Aug., Sept..........	9.91	11.31	3.79	15.10
Oct., Nov., Dec..........	8.77	1.00	1.41	2.41
Jan., Feb., Mar., 1923.....	15.70	1.42	Trace	1.42
Totals for last four periods.	44.64	15.62	6.96	22.58

At Fayette National Bank Bldg., Lexington, Ky.				
Jan., Feb., Mar., 1922	12.78	Not determined for this period		
Apr., May, June	10.28	1.61	7.33	8.94
July, Aug., Sept	10.40	2.57	3.54	6.11
Oct., Nov., Dec	8.01	4.29	2.35	6.64
Jan., Feb., Mar., 1923	15.87	2.59	2.51	5.10
Totals for last four periods	44.56	11.06	15.73	26.79

TABLE 2.—*Summary of nitrogen in the rainwater between April 1, 1922, and April 1, 1923.*

Location	Rainfall inches	Ammonia N per acre lbs.	Nitrate N per acre lbs.	Total N per acre lbs.
Russellville	42.36	14.01	3.57	17.58
Greenville	53.23	14.92	9.66	24.58
Mayfield	49.91	6.66	9.92	16.58
Lone Oak	37.70	7.83	6.37	14.20
Lincoln Ridge	28.73	10.60	6.52	17.12
Van Meter Farm	44.64	15.62	6.96	22.58
Average	42.76	11.61	7.17	18.78

TABLE 3.—*Nitrogen in rainwater by three-month periods.*

	Rainfall inches	Ammonia N per acre lbs.	Nitrate N per acre lbs.	Total N per acre lbs.
Jan., Feb., Mar., 1922	13.13	1.99	3.13	5.12
April, May, June	11.07	3.47	1.05	4.52
July, Aug., Sept	7.30	5.19	2.65	7.84
Oct., Nov., Dec	9.22	1.52	2.28	3.80
Jan., Feb., Mar., 1923	15.15	1.44	1.18	2.62

With an average rainfall of 42.76 inches for the year April 1, 1922, to April 1, 1923, in six different locations in Kentucky the soil received an average of 18.78 pounds of nitrogen per acre. Of this amount, 11.61 pounds was in the form of ammoniacal nitrogen and 7.17 pounds was in the form of nitrate nitrogen.

LITERATURE CITED

1. CHAMOT, D. S., PRATT, D. S., and REDFIELD, H. W. A study of the phenoldisulfonic acid method for the determination of nitrates in water. *In* Jour. Am. Chem Soc. 33:381–384. 1911.
2. OLSEN'S Quantitative Chemical Analysis, 5th revised edition, pp. 413–415.
3. WILSON, B. D. Nitrogen in the rainwater at Ithaca, New York. *In* Soil Sci. 11:101–110. 1921.

THE RELIABILITY OF A DIFFERENCE BETWEEN TWO AVERAGES[1]

W. B. KEMP[2]

Those who have occasion to interpret the results of crop investigations are very much indebted to Love and his coworkers for keeping constantly before them the necessity for applying some measure of reliability to the results of such studies. Anthony and Waring, together with these men, have brought to general attention the method of "Student," for measuring the reliability of a difference between two averages when this difference is determined under the peculiar conditions that exist in plot tests. Articles on this subject have compared the method of "Student" with an application of the ordinary formula or modifications of the ordinary formula as suggested by Bessel and by Peter. The "Student" method has given a measure of reliability that seems more reasonable than that obtained by these formulas. On account of this showing its use is recommended. In nearly all cases where such comparisons are made, the significance of results as measured by the two methods vary so widely that the casual reader is apt to doubt the reliability of either method. It is in an effort to overome such doubts that this article is written.

One very important consideration seems not to have been sufficiently stressed in these discussions. This consideration is the fact that superiority of "Student's" method to the applications of the other formulas is not primarily because of the paucity of data, even though this does have some effect, nor because of a too closely drawn "Analogy between determinations made in the exact sciences and the measurement of field plot trials." It is because Bessel's formula was never designed for use under such conditions and is, therefore, inadequate for this use. One of the specific limitations accompanying the use of Bessel's formula is that there shall be no correlation between the deviations in the sets of data from which the difference in average is determined. But correlation is almost sure to be present whenever any such deviations as those induced by season or soil can modify the data. If such correlation does exist, its effect must be removed either before or after the formula is applied. After this removal it may be of value to compare the merits of the different methods, but before its removal no comparison can logically be made, for the formulas referred to are patently inapplicable.

[1]Contribution from the Department of Agronomy, Maryland Agricultural Experiment Station, College Park, Md. Received for publication March 25, 1924.
[2]Associate Agronomist.

One would hardly go to the trouble to determine what correlation exists and then remove its effect from Bessel's formula unless such a procedure were obviously superior to the "Student" method; but occasions arise when it is desirable to measure the reliability of differences when the necessary correlations are at hand and under such conditions their use is justified.

To illustrate why such importance is attached to the correlation between paired comparisons, let an average difference between plots of a and b be determined, and let d_{a-b} be the deviation from this average of a difference in yield between two plots. Let d_a and d_b be the deviations of these plots from their respective averages.

Then—

$$d_{a-b} = d_a - d_b$$

To obtain a standard deviation, this must be squared. Accordingly—

$$d^2_{a-b} = d^2_a - 2d_a d_b + d^2_b$$

When this is summed (Σ) with other similar squared deviations there results—

$$\Sigma d^2_{a-b} = \Sigma d^2_a - 2\,\Sigma d_a d_b + \Sigma d^2_b$$

Divide by "N" the number of cases that make up the summation, and the average so obtained is—

$$\frac{\Sigma d^2_{a-b}}{N} = \frac{\Sigma d^2_a}{N} - \frac{2\Sigma d_a d_b}{N} + \frac{\Sigma d_b^2}{N}$$

But $\frac{\Sigma d^{2}_{a-b}}{N}$ is σ^2_{a-b}, the square of the standard deviation, and $\frac{\Sigma d_a d_b}{N}$ is "P", the product moment of a correlation table.

The correlation, "r" $= \frac{P}{\sigma_a \sigma_b}$

Therefore $P = r.\sigma_a\sigma_b$. Substituting in the above formula one finds that $\sigma^2_{a-b} = \sigma^2_a - 2r.\sigma_a\sigma_b + \sigma_b^2$.

When $r = o$ the middle term becomes o, and there results the usual formula, $\sigma^2_{a-b} = \sigma_a^2 + \sigma_b^2$

But when r is not o, this middle term cannot be omitted.

The probable error of such a difference is—

$$\pm .6745\sqrt{\frac{\sigma^2_{a-b}}{N}} = \pm .6745\sqrt{\frac{\sigma_a^2 + \sigma_b^2 - 2r.\sigma_a\sigma_b}{N}} \qquad (1)$$

When $r = o$ the last term may be omitted and there results—

$$\pm .6745\sqrt{\frac{\sigma^2_{a-b}}{N}} = \pm .6745\sqrt{\frac{\sigma_a^2 + \sigma_b^2}{N}} \text{ or } \pm .6745\sqrt{\frac{\Sigma d_a^2 + \Sigma d^2_b}{N^2}} \qquad (2)$$

Bessel's modification for use when "N" is small has been applied to

formula (2) in the comparisons under discussion. This modification should have been applied to (1) because the r values ran very high.

"Student" has not corrected for the correlated variation, but has removed it by subtracting the paired yields for each year or for each soil condition.[3] Love has suggested a like procedure even when Bessel's formula is to be used. Such a method, when the numbers are few, is simple and satisfactory. This is written, then, not to argue against such use, but rather to help overcome any uncertainty that may have been engendered on account of the observation that different methods show widely different results.

It is not logical to compare with "Student's" method any method that does not take into account the correlation that exists, because such a method is wrongly applied. It is logical to make such comparisons if the formulas used are complete, but in that case the glaring differences in reliability as measured by the different methods largely disappear.

It will save space and explanation if a problem is used for illustrative purposes that has been used formerly. On page 222 of this JOURNAL, for June, 1923, two varieties, A and B are compared. The results given are as follows:

	A	B
	79.6	77.2
	49.7	53.5
	46.5	66.1
	63.8	65.8
	42.4	52.4
	47.7	53.7
Average	54.9 ±3.9	62.0 ±2.6

By an application of Bessel's formula, a probability of significance is obtained that has been calculated as odds of 2.2:1. When this same formula is applied to the differences between pairs of yields, the odds change to about 40:1. When "Student's" method is used, the odds become 25.5:1. When odds as obtained by the use of established formulas vary between 2:1 and 40:1, one is inclined to doubt the reliability of any method. The opportunity for such doubts is un-

[3]Since writing this, there has come to hand an article by "Student" entitled, "On testing varieties of cereals," *in* Biometrika 15:271-293, December, 1923. In this article, much stress is laid upon the necessity for considering the correlation in formulas for error when applied to results of plot tests. Also, F. D. Richey, in an article entitled "Adjusting Yields to their Regression on a Moving Average as a Means of Correcting for Soil Heterogeneity" (*In* Jour. Agr. Research, 27: 79-90 1924) discusses the complete formula as described in this paper.

fortunate, since the three methods do not really give results so widely different, if the correlation is considered. The following comparison makes this clear.

Correlation between yields of A and B: +.854

Difference between average yield of A and B: 7.1

Application of Bessel's formula without considering the correlation: (Applied incorrectly)

$$\sqrt{\frac{\sigma_a^2+\sigma^2_b}{N-1}}=6.97. \quad \frac{7.1}{6.97}=1.02.\text{— Odds, } 2.2:1$$

($\pm .6745$ is omitted to facilitate calculation of odds from standard error.)

Same formula when correlation is considered: (Applied correctly)

$$\sqrt{\frac{\sigma^2_a+\sigma^2_b-2r.\sigma_a\sigma_b}{N-1}}=3.15. \quad \frac{7.1}{3.15}=2.22.\text{— Odds, } 36.8:1$$

Same formula when applied to difference between pairs:

$$\sqrt{\frac{\sigma^2_{a-b}}{N-1}}=3.15. \quad \frac{7.1}{3.15}=2.22.\text{— Odds, } 36.8:1$$

"Student's" Method:

$$Z=\frac{7.1}{7.048}=1.007 \quad P=.9623.\text{— Odds, } 25.5:1$$

When the ordinary formula is applied to this same data, the odds obtained are about 70:1; but it is generally considered that six is a number too small for use of this formula. As the number increases the results obtained from the use of this formula approach those obtained from the use of Bessel's formula. Since the odds of "Student" are calculated from a curve somewhat different in shape from the normal one, its size is not identical with that obtained from Bessel's formula. For all practical purposes, however, convenience rather than great difference in reliability will determine whether to use one method or another; but the general differences in comparative results should be kept in mind.

Since the appearance of the table prepared by Miss Feehan and presented by Love in the January, 1924, issue of this JOURNAL, the use of "Student's" method when numbers are few should require less work.

THE NITROGEN CONTENT OF KIRKLAND SILT LOAM AS INFLUENCED BY DIFFERENT CROPPING AND SOIL TREATMENT[1]

HENRY F. MURPHY[2]

The nitrogen problem is a very complex one. The inactivity of the gas and the need of crops for it are the foundation reasons. Yet there are many ways in which the combined nitrogen present in the soil can be partially controlled. All of these ways need to be studied very carefully in order to be most efficient as to the use of this very important substance. Some of the factors which affect the nitrogen content of soils are soil treatments, crops and cropping systems, and climatic factors. A vast amount of literature has been published concerning this problem and no attempt will be made in this short article to review it.

EXPERIMENTAL WORK

An experiment was started on the Oklahoma station farm in 1913, in which alfalfa was grown on manured and unmanured land. In 1916, a soil survey was made of the station farm and part of the experiment was discontinued. At that time, one-half of the untreated soil was limed with 2½ tons of ground limestone, as was also one-half of the manured ground. The soil on which this experiment is being conducted is Kirkland silt loam. A plot of adjoining land of this same type has been growing oats continuously since 1916. An analysis of this soil was made in 1916, showing, among other constituents, the amount of nitrogen present. In January, 1924, eight years later, an analysis showing the total nitrogen content of each

TABLE 1.—*Showing nitrogen content of all plots in 1924.*
(Average of duplicate determinations in each case)

Plot No.	Surface 6⅔ inches	Subsurface 6⅔ to 18 inches
	Percent	Percent
Land North 1* (1916)	0.1050	0.0910
" " 1	0.0918	0.0689
Plot 1	0.1146	0.1019
Opposite 1	0.0996	0.0775
Plot 2	0.1012	0.1189
Opposite 2	0.0978	0.0741
Plot 3	0.1304	0.0967
Opposite 3	0.1104	0.0658
Plot 4	0.1092	0.0983
Opposite 4	0.1098	0.0747

*This is the nitrogen content of the soil in 1916

[1]Contribution from the Department of Agronomy, Oklahoma Agricultural Experiment Station, Stillwater, Okla. Received for publication March 25, 1924.
[2]Associate Professor.

plot was made. These analyses are shown in Table 1. The crops grown and yields secured are given in Table 2.

TABLE 2.—*Showing yields of crops.*

Plot No.	Crop grown	Average annual yield per acre, 1916–1923
North 1	Oats continuously	36.97 bushels*
Plot 1	Alfalfa continuously	1970 pounds
Plot 2	" "	3086 "
Plot 3	" "	6261 "
Plot 4	" "	6814 "
Opposite 1	Various cereals and cotton	No data—Nursery plots
Opposite 2	" " " "	" " " "
Opposite 3	" " " "	" " " "
Opposite 4	" " " "	" " " "

*6 yr. average 1917–1922 inclusive. Crop failure 2 years on account of insects and late freezes.

SOIL TREATMENTS

Plots North 1, 1, Opposite 1, Opposite 2, Opposite 3, and Opposite 4 have received no soil treatment. Plot 2 received an application of 2½ tons of ground limestone in 1916. Plot 3 received an application of 12 tons of barnyard manure in 1913, while Plot 4 received 2½ tons of ground limestone in 1916 and 12 tons of manure in 1913.

EFFECT OF DIFFERENT CROPS

The difference in effect of crops having a different kind of root system is quite pronounced. In 1916, the surface soil (North 1, 1916) contained .1050% nitrogen and the subsurface .0910%. In the spring of 1916 this soil was planted to oats and has been planted to this same crop every year since. At the end of 8 years, the soil (North 1) contains .0918% nitrogen in the surface and .0689% in the subsurface. The same type of soil immediately adjoining was planted to alfalfa in 1913 and has grown alfalfa continuously since. It (Plot 1) shows at the present time .1146% nitrogen in the surface and .1019% in the subsurface. Another block of soil of the same type adjoining these plots (Opposite 1) has grown some cereal, or cotton, practically every year. It shows .0996% nitrogen in the surface and .0775% in the subsurface.

The results show that cereals have reduced the nitrogen content of the surface soil. With oats grown continuously, this amounts to 264 pounds of nitrogen per acre below what the original soil contained, or an average loss of 33 pounds per acre annually. The plot on which cereals of various kinds and cotton have been grown does not show so great a loss, but even this one shows an average annual loss of 13.5 pounds per acre. The land on which alfalfa is growing shows a gain in nitrogen content. Very similar results occurred in the subsurface. Oats grown continuously reduced the nitrogen content, as did the various cereal and cotton treatments, while the alfalfa plot shows a

gain. Both the grain and straw on the oat plot were removed each year, while from the various cereal and cotton crops (unless a small grain was grown) the stalks were left on the ground. The alfalfa crop was removed as hay each year.

On every plot where alfalfa was grown the nitrogen content of the subsurface in 1924 is greater than in 1916. This is shown in Table 3.

TABLE 3.—*Showing nitrogen content of subsurface soil, as affected by alfalfa grown continuously for eight years.*

Plot No.		Nitrogen in subsurface soil Percent
North 1	1916 analysis	0.0910
1	Alfalfa grown continuously (untreated)	0.1019
2	" " " (limed)	0.1189
3	" " " (manured)	0.0967
4	" " " (manured and limed)	0.0983

This shows that alfalfa is valuable in increasing the nitrogen content of the subsurface soil even when the tops of the plant are removed as hay. Very similar data were obtained for the surface soil, as shown in Table 4.

TABLE 4.—*Showing nitrogen content of surface soil, as affected by alfalfa grown continuously for eight years.*

Plot No.		Nitrogen in surface soil Percent
North 1	1916 analysis	0.1050
1	Alfalfa grown continuously (untreated)	0.1146
2	" " " (limed)	0.1012
3	" " " (manured)	0.1304
4	" " " (manured and limed)	0.1092

In this case an exception occurs with Plot 2, in that it is not quite as high as the untreated land in 1916, although this difference is small. The subsurface of this plot is, however, very much higher in nitrogen than was shown in 1916 and consequently the average nitrogen content of the first 18 inches of soil is much higher than the original.

Effect of Different Soil Treatments

Where lime was applied to alfalfa (Plot 2), the nitrogen content of the surface soil is just a little below the content in 1916, while the subsurface shows a gain. The yield of alfalfa was greater on Plot 2 than Plot 1. Lime tends to increase bacterial activity and nitrogen fixation. It would seem that the increase in yield of alfalfa was not in proportion to the nitrogen fixed by the bacteria in the surface soils while more nitrogen fixation took place in the subsurface than in the case of Plot 1. This would seem to show that the nitrogen necessary for the increased yield was taken largely from the surface soil in the case where lime is applied. A study of the results from Plot 4 seems to bear out this assumption. The same amount of manure was

applied to Plot 4 as to Plot 3, yet Plot 3 has much the larger quantity of nitrogen in the surface soil. A part of this difference may be accounted for in the slightly higher yield obtained on Plot 4; but certainly not all of it is due to this cause, because the total increase in yield for the 8-year period amounts to only 4424 pounds of alfalfa. Estimating that one ton of alfalfa hay contains 40 pounds of nitrogen this would mean 88.5 pounds of nitrogen for the extra yield, yet the surface soil of Plot 4 contains 424 pounds per acre less nitrogen than does that of Plot 3.

A further study of the subsurface of these plots would also tend to bear out the assumption that on limed soil the alfalfa takes most of its nitrogen from the surface. Plot 1 which is untreated contains 0.1019% nitrogen, while the limed plot adjoining contains 0.1189%. The subsurface in the manured plots bear a similar relation. Where manure alone was used, the subsurface soil has a nitrogen content of 0.0967%; while where lime was applied the subsurface soil shows 0.0983% nitrogen. Thus, where lime was applied either on soil not otherwise treated, or where treated with manure, the nitrogen content of the surface soil is somewhat lower than the respective plots not limed. At the same time the subsurface soils show a higher nitrogen content than the respective check or manured alone plots. With any of the soil treatments, where alfalfa is grown, the nitrogen content of the subsurface is greater at the end of the 8 years than at the beginning. For the other cropping systems, the nitrogen content of the subsurface has decreased considerably and is generally slightly decreased in the surface soil.

Acknowledgments

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AN EXPERIMENTAL STUDY OF THE VARIETY AS AN AGRONOMIC UNIT IN WHEAT AND OATS[1]

L. J. Stadler[2]

Although the variety is essentially a morphological group, it is used in agronomy chiefly as a physiological unit. A large proportion of current experimental work in crop production consists of the test-

[1]Contribution from the Department of Field Crops, University of Missouri, Columbia, Mo. Received for Publication March 17, 1924.
[2]Assistant Professor.

ing of varieties for yield and reaction to specific environmental factors (diseases, insect injuries, drought, cold, and the like.) Plant improvement projects are based on these variety tests to a considerable extent, selection being limited to the varieties found most productive. The ultimate object is to find the most productive seed stocks for practical crop production, and the principal function of the variety is in simplifying this task. Thousands of seed stocks varying in productivity are available to the farmer. The agronomist must help to choose one of these stocks as seed for his crop. Obviously, the agronomist cannot test all of the available stocks. But all of these stocks can be grouped in a relatively small number of morphological types, or varieties. The agronomist tests a representative of each of these varieties, and, on the basis of its performance, recommends or condemns the variety as a whole.

Thus, the variety test involves the assumption that all stocks meeting a certain taxonomic description are similar in the physiological characters which determine yield and economic value. If the stock representing Fulcaster in the variety test outyield all other stocks tested, Fulcaster wheat in general is recommended. In other words, all wheat conforming to a certain standard taxonomic description is recommended on the basis of the performance of one stock of that description. Of course, no agronomist believes that all plants belonging to the same variety are physiologically identical. The effectiveness of pure line selection demonstrates that considerable diversity occurs within most crop varieties. But the variety is tacitly assumed to be a fairly homogeneous group of closely related and similar plants, differing somewhat from one another, but distinctly differing as a group from other groups of different taxonomic character. This assumption is implied in every variety test in which conclusions are drawn regarding the variety as a whole. Within the limits of its experimental accuracy, the variety test determines the relative value of the stocks tested. But it does not determine the relative value of the varieties they represent, unless its basic assumption—that different stocks of the same variety are of practically equal economic value—is correct.

This fundamental assumption, which underlies so large a proportion of past and current experimental work in crop production, seems to have been quite generally accepted without any adequate experimental basis. This paper is a preliminary report of some of the results obtained in an investigation of this question at the Missouri Station during the last five years.

EXPERIMENTAL WORK

The object of this experiment is to determine the extent of variation in yield and other economic characters between pure and typical seed stocks within representative varieties of wheat and oats. The varieties used were Red Rustproof, Kherson, and Sixty-Day oats, and Fulcaster, Poole, and Red May wheat. The stocks tested were such as might have been obtained by a farmer in following the recommendations of an experiment station, or by an experiment station in beginning a variety test. These stocks were obtained from the United States Department of Agriculture, various state experiment stations, seedsmen, and Missouri farmers. Samples were requested under the names of the varieties mentioned above or their synonyms, as given by Etheridge (2)[3] for oats and by Clark, Martin, and Ball (1) for wheat. All stocks which were not ninety percent pure and true to the standard types, as described by these authorities, were discarded. Other stocks, containing an appreciable percentage of impurity, were purified by roguing before being included in the yield tests.

The yield tests of 1919 and 1921 were in quadruplicate 5-row blocks, planted with a 5-row nursery drill. The rows were 10 inches apart and 18 feet long, cut to 16 feet in harvesting. Only the interior rows were considered in determining the yields. The plot technic followed in these tests has been described in an earlier paper (3). In order to permit more replication of plots and the inclusion of a larger number of strains, single-row plots were used in 1920, 1922, and 1923. These rows were hand-seeded and were of the same dimensions as those mentioned above. The number of replications in these tests varied from eight to twelve. In all tests, check plots of the Station stock of the variety concerned were included as a basis for the determination of the probable error. The yields given are the actual (unadjusted) yields.

Kherson and Sixty-Day stocks were included in the same test, since these varieties are practically indistinguishable. Etheridge has applied the name "Kherson" to plants with yellow grains, and "Sixty-Day" to plants with white grains. The original importations of both Kherson and Sixty-Day contained a mixture of yellow and white grains, and most of the seed stocks now on the market, except those resulting from pure line selections, contain grains of both colors. In these experiments, therefore, no attempt was made to separate Kherson and Sixty-Day stocks. The two names were considered synonymous, following Warburton and Stanton (4). The proportions

[3]Reference by number is to "Literature Cited," p. 371.

of white and yellow grains in each stock were determined by count, in each of the four seasons in which Kherson and Sixty-Day stocks were tested. No significant relation between color of grain and yield was found, nor did the stocks obtained under the name Kherson differ significantly in yield from those obtained under the name Sixty-Day.

The range in yield of the stocks of each variety tested is shown in Table 1. This table summarizes the results of thirteen independent experiments, in each of which several stocks of a single variety of wheat or oats were compared in yield. Thus, line 8 of the table means that, in 1922, forty-seven different stocks of Fulcaster wheat were included in a comparative yield test, each in nine replicate plots; that the lowest yielding stock yielded 17.8 bushels per acre, and the highest yielding stock 32.0 bushels per acre; and that the probable error determined from the check plots was such that the average yield of 9 replicate plots would be assigned a probable error of 1.28 bushels.

In each case, the stocks of a single variety differed in yield by a considerable amount, well beyond the limits of experimental error. The relative range in yield is considerably greater in some cases than in others, a fact partly due to the different numbers of stocks tested. Each of the thirteen trials indicates too wide a range in yield to justify the use of the variety as an agronomic unit.

It is possible that, in the experiments of 1920, 1922, and 1923, in which single rod-row plots were used, the range of variation in yield was increased by competition between stocks grown in adjoining rows. Competition in a test of strains, or stocks, of the same variety is probably not so great a source of error as is competition between different varieties (3), but it is probable that when extremely high-yielding and low-yielding stocks happened to be grown side by side the difference between their yields was increased by competition. In these preliminary experiments, it was necessary to use single-row plots in order to permit the comparison of a large number of stocks with a fairly large number of replications. The probable importance of competition in determining the yield differences can be roughly estimated from the relative yields of stocks in adjoining rows. When a very high-yielding stock occurs between two low-yielding stocks, it may fairly be assumed that its yield was increased somewhat by its advantage in competition. Some of the extreme yields, both high and low, are questionable on this account. But in each single-row test wide differences in yield may also be found, which could hardly have been materially affected by competition. Furthermore, the fact

TABLE 1.—*Variation in yield among commercial stocks of the same variety*

Variety	Season	Number of stocks tested	Number of replicate plots	Yield (bushels per acre)			Probable errors of yields
				Lowest	Highest	Range	
Oats							
(1) Red Rustproof	1919	12	4	59.0	71.9	12.9	±1.39
(2) Red Rustproof	1920	8	10	25.9	36.0	10.1	±1.54
(3) Red Rustproof	1921	30	4	13.9	29.4	15.5	±1.42
(4) Kherson (Sixty-Day)	1920	12	10	28.9	51.7	22.8	±1.54
(5) Kherson (Sixty-Day)	1921	31	4	25.3	43.7	18.4	±1.42
(6) Kherson (Sixty-Day)	1922	59	12	19.8	29.7	9.9	±1.01
(7) Kherson (Sixty-Day)	1923	58	8	34.4	55.5	21.1	±1.46
Wheat							
(8) Fulcaster	1922	47	9	17.8	32.0	14.2	±1.28
(9) Fulcaster	1923	50	9	9.0	26.4	17.4	±0.96
(10) Poole	1922	15	9	20.1	29.7	9.6	±1.07
(11) Poole	1923	15	9	14.6	23.1	8.5	±0.59
(12) Red May	1922	14	9	21.8	31.1	9.3	±1.07
(13) Red May	1923	15	9	13.0	22.6	9.6	±0.73

that competition has occurred would be in itself an evidence of rather wide agronomic differences between the stocks compared.

The stocks of Fulcaster, Poole, and Red May were grown on adjoining plots in 1922, and their yields in this season are directly comparable. The variation within each of these varieties was far greater than the variation between their average yields. In other words, the results of a variety test including these three varieties would be entirely dependent upon the stocks which happened to represent them. A good strain of Fulcaster would far out-yield a poor strain of Poole, but a good strain of Poole would just as clearly out-yield a poor strain of Fulcaster. It happens that the Missouri Station stock of Fulcaster is one of the best of the Fulcaster stocks tested, and this may in part account for the fact that Fulcaster has been the highest yielding variety of wheat in the varietal experiments of this Station. If the Station had happened to obtain one of the poorer yielding stocks of Fulcaster when the variety tests were begun, it might now condemn this variety as unadapted to Missouri conditions.

In short, it seems that general varietal recommendations may frequently be in error because the stock included in the variety test does not fairly represent the variety to which the conclusions are applied. The result of the variety test may properly be applied only to the strains actually tested. In the case of pure line varieties all available stocks may be known to belong to the same strain, but in the case of ordinary commercial varieties, not known to be pure lines, there is no reason to assume that the stocks meeting the same taxonomic descriptions are necessarily similar in yield and value. Although Fultz may have been unsatisfactory in the variety test, other stocks of Fultz may be very valuable. In plant improvement it is not safe to confine attention to varieties recommended as a result of variety tests. It is probably desirable to maintain a continual variety or strain test in which as many different stocks as possible, regardless of their varietal classification, may be tested, new stocks being introduced constantly as old ones are eliminated. This is of course an unending task, for the number of available stocks is infinite, but it may supply the plant breeder with a never-failing source of raw material for further improvement.

LITERATURE CITED

1. Clark, J. Allen, Martin, J. H., and Ball, Carleton R. Classification of American wheat varieties. U. S. Dept. Agr. Bull. 1074. 1922.
2. Etheridge, W. C. A classification of the varieties of cultivated oats. N. Y. (Cornell) Agr. Exp. Sta. Mem. 10. 1916.

3. STADLER, L. J. Experiments in field plot technic for the preliminary determination of comparative yields in the small grains. Mo. Agr. Exp. Sta. Res. Bul. 49. 1921.
4. WARBURTON, C. W., and STANTON, T. R. Experiments with Kherson and Sixty-day oats. U. S. Dept. Agr. Bul. 823. 1920.

THE USE OF THE WORDS ANALYSIS AND FORMULA IN REFERENCE TO COMMERCIAL FERTILIZERS[1]

T. K. WOLFE[2]

Should "analysis" or "formula" be used to refer to the percentages of ammonia, phosphoric acid and potash in a commercial fertilizer? There is, at the present time, a lack of uniformity in regard to the use of these two words. A recent issue of a farmers' magazine, important in those states where commercial fertilizers are used in large quantities, used the words *analysis* and *formula* at different places in the same article to refer to the percentages of ammonia, phosphoric acid and potash. Some textbooks on soils refer to these percentages by the use of the word *formula* and others by the use of the word *analysis*. Unless these two words are synonymous, they should not be used to designate identical ideas. Uniformity in usage of words is always preferable.

The fertilizer industry uses the word *analysis* to refer to the percentage of ammonia, phosphoric acid and potash contained in a fertilizer. Thus, a 3–8–3 fertilizer is one which contains 3 percent of total nitrogen calculated as NH_3, 8 percent "available" phosphorus calculated as P_2O_5, and 3 percent of water-soluble potassium calculated as K_2O. Many agronomists are using the word *analysis* with the same meaning as that used by the fertilizer industry. Other agronomists are using the word *formula* rather than *analysis*.

A study of the derivation of the two words will give an insight as to their proper usage. The word *analysis* is derived from two Greek words, *ana*, up, and *luein*, to loose, with the meaning to unloose, to resolve. The word *formula* is derived from the Latin word *forma*, meaning a model. The formula for a fertilizer refers to the recipe or model, by which a mixed commercial fertilizer is made, after the analysis of the various materials to be used in making it is known. The analysis, therefore, logically precedes the formula. If the analysis of the proper materials is known, it is easy to calculate the amount of each necessary to compound a mixed fertilizer and to give the

[1]Contribution from the Department of Agronomy, Virginia Agricultural Experiment Station, Blacksburg, Virginia. Received for publication March 27, 1924.
[2]Agronomist.

formula for making it. A fertilizer having a given analysis may be made by the use of any one of several formulas. A good illustration of this fact is the use of the fertilizer having a 3–8–3 analysis for dark and bright tobaccos in Virginia. This analysis has proved to be the best yet tested for these types of tobacco under Virginia conditions. However, the formula, or recipe, for making a 3–8–3 fertilizer for bright tobacco is different from that for dark tobacco. The difference is concerned with the source of ammonia. For bright tobacco, it is recommended that two-thirds of the ammonia come from an inorganic source, such as nitrate of soda or ammonium sulphate, and one-third from an organic source, as tankage or fish scrap. For dark tobacco, the recommendation is that one-third of the nitrogen come from the inorganic source and two-thirds from the organic.

Both the derivation of the words and the present usage indicate that, so far as commercial fertilizers are concerned, the word "analysis" should be used to refer to the percentages of ammonia, phosphoric acid and potash, and the word "formula" to the recipe for compounding the mixture.

BACTERIAL SYMBIOSIS IN PLANTS OTHER THAN THE LEGUMES[1]

J. K. Wilson[2]

Symbiosis, as usually defined, means the mutual living together of two individuals in which each receives some helpful contribution from the other. An especially interesting example is furnished by leguminous plants and the bacteria living in their root nodules. Probably, however, examples just as interesting may be furnished by other families of plants in which the bacteria live and develop colonies either in the roots or in the above ground parts.

It is the purpose of this review to point out some of the probable symbiotic relations existing between certain plant families, other than the leguminoseae and bacteria. For convenience of discussion, these relations may be divided into two parts. First, that form of symbiosis in which the bacteria or fungi live in nodules in the roots as in the leguminous family; and second, that in which the bacteria live mostly in those parts of the plant which grow above the ground. Only the latter form will be reviewed at this time.

As early as 1887, Galeppe (1)[3] reported the presence of bacteria

[1]Contribution from the Department of Agronomy, Cornell University, Ithaca, New York. Received for publication March 31, 1924.
[2]Professor.
[3]Reference by number is to "Literature Cited," p. 380.

within vegetable tissues. Sections of tissues of various plants when transferred aseptically to sterile medium nearly always produced bacterial growth.

In 1890, Treub (2) observed an association between *Spathodea Campanulata* Beauv. and certain bacteria which developed in the flowering parts. These bacteria which seemed to have had no bad effect upon the floral parts of the plant appeared most abundantly at the time of greatest secretion of liquids in the calyx. As the flower matured the liquid became putrid and ammoniacal.

Seven years later, Koorders (3) studied the bloom bud hydathodes of certain tropical plants and found symbiotic relations existing between certain host plants and bacteria or fungi. The following summary of his results is of interest:

Plant	Organism in 'wasserkelchen'	Reaction of liquid
Spathodeae campanulata	Bacteria	Alkaline
Clerondendron minahasse	Bacteria	Alkaline
Parmentiera cerifera	Fungi	Alkaline (Sap of plant acid)
Crescentia cujete	Fungi	———
Heterophragma adenophyllum	Fungi	Acid
Kegelia pennata	Bacteria	Alkaline
Sterospermum hypostictum	Fungi (no bacteria seen)	Acid
Juanulloa parasitica	Fungi	Alkaline
Nicandra physaloides	Bacteria (no fungi seen)	Alkaline

It may be seen from this summary that both bacteria and fungi were found by Koorders in the bloom hydathode secretion and that, in most of the cases reported, the water was alkaline. The composition of this liquid varied somewhat with age, but the following is given for *Spathodeae campanulata:* solids 0.65%, of this 0.45% was ash. This ash was largely carbonates, nitrates and sulphates of potassium, sodium and calcium.

The following have been investigated by Koorders:

Family: *Bignoniaceae;* (1) *Spathodeae campanulata* Beauv., (2) *Paramentiera cerifera* Seem., (3) *Crescentia cujete* Linn., (4) *Kigelia pinnata* D. C., (5) *Heterophragma adenophyllum* Seem. (*Dolichandrone adenophyllum Raciborski.*)

Family: *Solanaceae*; (1) *Jochroma macrocalyx* Benth., (2) *Juanulloa parasitica* Ruiz. et Pav., (3) *Nicandra physaloides* Gartn.

Family: *Verbenaceae*; (1) *Clerodendron minehassae* Teysm. et Binn., (2) *Clerodendron splendens* Don.

Family: *Scrophulariaceae*; (1) *Ilysanthes* (Bonnaya) spec.

Family: *Zingiberaceae*; (1) Alpine spec.

In addition to these green plants, certain dried specimens have been examined. These include under the *Bignoniaceae: Markjamia lutea* Serm., *Dolichandrone tomentosa*, Senmr., and *Heterophragm* spec.: and under *Melastomaceae*; *Bellucia* and *Myriaspora* spec. div. and *Kibessia echinata* Cong.

In all these plants, representing six families and nineteen species, either bacteria or fungi have been found. Their constant presence on the floral parts led Koorders to state that they were of the greatest importance in this association. He held, like Treub, that they were normal to the plants and necessary to the development of fruit. A further explanation of their presence was not offered.

From the foregoing it is evident that bacteria may be found in plant tissues and in the floral parts of many plants. However, Trimen was the first to locate nodules in the leaves of the *Rubiaceen* family and Zimmerman (4) was the first to show that these nodules were filled with bacteria. Zimmerman's observations were confined to four species of a single family—*Rubiaceen*.

Researches on *Pavetta lanceolata* revealed nodules on the leaves similar to those described by Trimen. They were visible as bright green spots on the upper side of the leaves and were about ½ mm. in diameter. Over the middle of the nodule was a depression in the epidermis. Under this lay a circular webbed body. When stained with haematoxylin and examined, nuclei, starch, and chromatophores were found. The cells in the webbed part and around it, when stained with potassium iodide, were blue. The bacteria were found within this cell mass, but no cells were penetrated by the organism. Cover glass preparations of the organisms were easy to make. Histological studies revealed that the nodule was started when the leaf was still in the bud. As the leaf developed the bacteria entered the tissue cell space through an opening which may have been a stomata. Further development of the leaf resulted in the opening becoming smaller and eventually closed and covered with cuticle. Finally, there were several cells between the space occupied by the bacteria and the top of the leaf.

Observations by Zimmerman of leaf nodule development on *Pavetta angustifolia* were very much the same as those on *Pavetta lanceloata*. The nodules appeared on the under side of the leaf as dark green knots, 1 mm. in diameter, and on the upper side of the leaf just over the nodule there was a crater-like appearance. The bacteria were found both in chains and longer forms, and the author was in doubt whether the two forms were the same.

Working with *Pavetta indica*, Zimmerman found the plants to have a greater number of nodules which were scattered over a greater surface than was the case with the two plants just discussed. These nodules were observable on both sides of the leaf and appeared as dark green spots. The crater on the upper side of the leaf was scarcely, or not at all, visible. The nodules were 1 to 1½ mm. in diameter and anatomical studies revealed conditions very much the same as in *Pavetta angustifolia*. The nodules were filled with bacteria which were, for the most part, rod-shaped, 3 to 4 microns long and were entirely different from those in *Pavetta lanceolata*.

The fourth member of this family, which Zimmerman worked with, was *Grumilea mikrantha*. The nodules on the leaves of this plant were along the midrib of the leaf and the larger veins leading therefrom. They were about 8 mm. long and 1 mm. broad. On the upper side of the leaf just over the nodule was a deep groove. The nodules also appeared on the young leaves before they were fully grown and on examination the bacteria could be seen. This species has the same intracellular bacteria as that of *Pavetta indica*.

These observations of Zimmerman show that four *Rubiaceen* species have nodules on the leaves and that bacteria are in the intracellular spaces. No data are given to show the probable effect of this bacterial growth and nodule development upon the growth of the plant. Zimmerman suggests symbiosis and bases his opinion on such observations as green tissues, starch, etc.

Not until Miehe (5) reported his observations of *Myrsinaceen* (*Ardisia crispa*) was the source and cycle of the organism apprehended. Miehe traced the bacteria thruout the entire life of the plants from seed to maturity. In the seed, the bacteria were found between the embryo and the endosperm. As the young plants grew, the bacteria followed the growing tip to the new parts of the plant as they were developed. The bacteria were found eventually thruout the entire plant and developed in masses in the intercellular spaces. When the fruit developed, the bacteria were enclosed in the embryo sack and remained with the seed when the latter became full grown. This was described as the complete cycle.

Subsequently Miehe (6) isolated the organism and described its growth on a number of media. Microscopic examinations of the organism were made and measurements recorded. He assigned to it the name *Bacillus follicola*. In some pure culture determinations, the organism fixed as much as 1.21 mgs. nitrogen, in other cases none. Miehe drew the conclusion that the organism fixed nitrogen.

Miehe suggests that this is a case of hereditary symbiosis and thinks that the findings of Zimmerman, with the *Rubiaceen*, may be similar in this respect. The usefulness of such an hereditary association is evident when *Ardisia* is grown both with and without the bacteria, although no controlled inoculation experiments are recorded by him.

Boas (7) confirmed the findings of Zimmerman, in regard to anatomical relations and bacterial presence, and extended the list of plants in the *Rubiaceen* which have nodules in the leaves. In a summary, Boas presents the present knowledge concerning the plants which have bacterial leaf nodules. They are:

Rubiaceen: Pavetta indica, P. lanceolata, P. angustifolia, Grumilea mikrantha. Psychotria alsophila, Ps. umbellata and *Ps. Bacteriophila.*

Myrsinaceen: Ardisia crispa.

Boas believes these different families are not subject to this form of bacterial disease, but that probably the bacteria play a more or less important role in the life of the plant.

Simultaneously with the work which was being conducted by Miehe and by Boas, von Faber (8) was studying the possible symbiosis existing between bacteria and certain tropical plants. Working with *Pavetta indica* L., *P. angustifolia* Thu., *P. lanceolata* Ekl., *P. Zimmermanniana* Val., and *Psychotria bacteriophila* Val., he not only observed the nodules and isolated the organism but also determined the ability of the organism to produce nodules as well as its ability to fix nitrogen both in association with its host plant and in pure cultures.

Von Faber's description (9) of the nodules and their development agrees in the main with that given by previous observers and he states that hereditary living together of bacteria and the *Rubiaceen* is a common occurrence. In this family, all sub-species show this form of symbiosis. Trimen observed this in Ceylon, Winkler in Borneo, and Boas in Java.

The bacteria were observed by von Faber in the seed, in the plant buds, and in the nodules on the leaves. They were easily isolated from the latter and grew well in a decoction of young leaves, gum arabicum, asparagin, di-potassium phosphate, and sufficient calcium carbonate to neutralize the medium. Solid medium for colony formation consisted of the above with the addition of agar. On this solid medium, after five days, colonies appeared as small milky-white points. In 20 days, the colonies may be 2 to 3 mm. in diameter.

When removed with a needle, they were inclined to be viscous, resembling the leguminous organism in this particular.

Microscopic examinations of the organism from leaf nodules and from plate colonies gave considerable variation both in size and shape. Many irregular X and Y forms were observed. von Faber places the organism among the mycobacteria because it is single celled, irregular, rod-form, has no mycelium and no spores, and is non-motile. This is the same classification as Miehe gave to the organism from *Ardisia* (*Myrsinaceen*). Many of the salient characters of the organisms were determined. One of special interest in this connection was nitrogen fixation.

Nitrogen Fixation by Bacteria from Leaf Nodules of the Rubiaceen (von Faber)

A number of tests were made to determine the nitrogen-fixing power of the organism. Cultures known to effect inoculation were used. These were grown in a solution composed of the following. Decoction of seeds of *Pavetta Zimmermanniana* with 2% gum arabicum, 0.5% potassium di-hydrogen phosphate and sufficient calcium carbonate to neutralize the medium; 100 cc. of this were inoculated and incubated twenty days. The following summary shows the nitrogen in 200 cc. of the medium.

In control	In culture	Increase
12.256 mg.	21.950 mg.	9.694 mg.
12.256	31.848	19.592
12.243	24.102	11.243
12.243	25.006	12.750

The second test to determine nitrogen-fixation was conducted in a nitrogen-free medium. In 1000 cc. of water, the following were added: 20 gm. gum arabicum, 0.5 gm. KH_2PO_4, 0.01 gm. $MgSO_4$, 0.5 gm. $CaCO_3$ and traces of NaCl and $FeSO_4$. 100 cc. portions of this solution were inoculated with pure cultures from *Pavetta Zimmermanniana* and incubated twenty days. The nitrogen in 200 cc. at the close of the experiment is shown in the following tabulation.

In control	Inoculated	Increase
1.232 mg.	7.642 mg.	6.230 mg.
1.232	6.360	5.128
1.232	2.456	1.224
1.232	7.233	6.001

Another test was conducted in which 0.1% asparagin was added and increases of 8.202, 13.994, and 5.369 milligrams of nitrogen were reported.

Von Faber concludes from these results that the organism fixes nitrogen when in pure culture, and a greater fixation is observed when a small amount of nitrogen is furnished in the culture medium.

As evidence of symbiosis between the *Rubiaceen* and bacteria *Pavetta Zimmermanniana* seeds were freed from the bacteria by treatment with hot water and plants grown in the absence of the bacterial symbiant. They were compared with plants naturally inoculated. The results show that bacteria-free plants in ordinary earth were never as good as those containing bacteria. By the time the bacteria-free plants had their first two leaves developed, the bacteria-containing plants had three to four leaves. After six month's growth, bacteria-free plants were on an average 8 cm. high, with an average of four pairs of leaves; while the bacteria-containing plants showed an average height of 14–15 cm. and seven to eight pairs of leaves. In the former, the leaves were 3–5 cm. long, while in the latter they were 4–8 cm. in length.

When similar experiments were conducted in sand, without fixed nitrogen, it was evident that the plants with which bacteria were associated were able to get their nitrogen supply from the air. Those plants which were without bacteria developed slowly, their leaves were yellow green, and the plants showed nitrogen starvation.

In water cultures to determine the symbiotic nitrogen fixation, the greatest care was exercised to prevent contamination by absorption of ammonia. Nitrogen-free chemicals were used. A nutrient solution known to give good plant growth was used. An experiment with *P. Zimmermanniana* lasted three months and gave the following results:

	Nitrogen in dry matter grams	Nitrogen increase grams
Bacteria-free plants without nitrogen....	0.0175	—0.0017
	0.0185	+0.0003
	0.0158	—0.0240
	0.0584	+0.0402
Bacteria-free plants with nitrogen.......	0.0276	+0.0094
	0.0442	+0.0260
	0.0288	+0.0106
	0.1174	+0.0992
Bacteria-containing plants without nitrogen	0.0885	+0.0704
	0.1151	+0.0969
	0.1624	+0.1442
Bacteria and plant with nitrogen.......	0.1446	+0.1264
	0.1824	+0.1642

It may be noted that plants grown without access to nitrogen other than that contained in the seed, when supplied with the bacterial symbiont, increased their nitrogen content approximately three to

six times. The author concludes that the plants with bacteria can secure their supply of nitrogen from the air.

Von Faber refers to the observations of Miehe on *Myrsinaceen* and compares them with his own on the *Rubiaceen*. Except for a few minor details the development of nodules on the plants of the two families is very similar. The bacteria of *Ardisia* resemble those of the *Rubiaceen* though there are some differences. In both cases, however, von Faber assumes that the bacteria draw their energy from the secretions of the surrounding cell membrane since they develop extracellular.

Von Faber extended the observation of Miehe as regards symbiosis of bacteria with *Ardisia*. While Miehe worked with *A. cumingiana* A. DC. & A. Goenoeny Tjislak, von Faber examined *A. crenulata* Lodd and *A. djampang*. On these, he observed bacteria in the vegetative points. Seeds were not at his disposal. Thirty other *Ardisia* were examined. He found all except one abundantly supplied with bacteria in the buds. Seeds of these thirty species were also not at his disposal.

SUMMARY

The gradual accumulation of data on this subject of bacterial symbiosis in plants other than the legumes leads one to make the following statements:

Bacteria may be found not only in the tissues of a great number of plants but also in the buds, flowers and seeds.

In certain cases, the bacteria which are found in the seed may pass thru the tissue of the growing plantlet and subsequently appear in the leaves and bloom and finally enter and remain with the growing seed. This condition may be called hereditary symbiosis.

In two families, the *Myrsinaceen* and the *Rubiaceen*, hereditary symbiosis has been observed; while it is suggested in many others.

The bacteria in symbiosis with the *Rubiaceen* enable the latter to secure the free nitrogen from the air for its own use.

These bacteria from plants of the Rubiaceen family and possibly from the Myrsinaceen family, when grown under suitable conditions in culture medium, increase the nitrogen content perceptibly.

Rubiaceen plants, when deprived of the bacteria and grown in a nitrogen-poor substratum, show nitrogen starvation and fail to increase their nitrogen content.

Myrsinaceen plants when deprived of their bacterial symbiant, grow poorly and show nitrogen starvation.

1. GALEPPE, V. Note sur la presence de micro-organisms dans les tissus vegetaux. *In* Compt. Rend. Hebd. de la Soc. de Biol. Ser. 8: Tome 4 410–416, 557–560. 1887.

2. TREUB, M. Les bourgeons floraux du *Spathodea Campanulata* Beauv, *In* Ann. du Jardin (Botanique) de Buitenzorg. 8:38–46. 1890.
3. KOORDERS, S. H. Ueber die blüthenknospen hydathoden einiger tropischen pflanzen. *In* Ann. du Jardin (Botanique) du Buitenzorg 14:354–477. 1897.
4. ZIMMERMANN, A. Ueber bakterienknoten in den blättern einiger *Rubiaceen* *In* Jahrb. f. wis. Bot. 37:1–11. 1901–02.
5. MIEHE, HUGO. Die sogennanten eiweissdrüsen an den blättern von *Ardisia crispa*. A. DC. *In* Ber. d. d. Bot. Gesells. 29:156–157. 1911–12.
6. ———. Weitere untersuchungen über die bakteriensymbiose bei *Ardisia crispa*. I. Die Microorganismen. *In* Jahrb. f. wiss. Bot. 53:1–55. 1913–14.
7. BOAS, F. Zwei neue workommen von bakterienknoten in blättern von *Rubiaceen*. *In* Ber. d. d. Bot. Gesells. 29:416–418. 1911–12.
8. v. FABER, F. C. Das erbliche zusammenleben von bakterien und tropischen pflanzen. *In* Jahrb. f. wiss. Bot. 51:285–375. 1912.
9. ———. Die bakteriensymbiose der *Rubiaceen*. *In* Jahrb. f. wiss. Bot. 54:243–264. 1914.

THE WEATHER AS A FACTOR IN CROP PRODUCTION[1]

F. L. MUSBACH AND M. L. KING[2]

In experimental work with fertilizers, one of the important questions with which investigators are concerned is the effect of various treatments on crop yields. It is known, of course, that very frequently the fertilizer effects are masked by weather conditions to such an extent that it is impossible to obtain consistent results which may be ascribed to any particular treatment. This is especially true on the lighter sandy types of soil. The distribution as well as the total amount of rainfall, and the temperature conditions must, therefore, be taken into consideration in interpreting yields obtained during any one year.

At the Spooner Branch Experiment Station, the writers have had occasion to study the effect of temperature and precipitation on the yields of corn during the years 1918, 1919 and 1920. The station is located in the jack pine belt, the soil of which is mapped as Plainfield sandy loam by the Wisconsin soil survey. The soil mass contains considerable fine and medium sand with some gravelly material in the surface soil. The subsoil is sandy and gravelly in character. The soil type is influenced markedly by moisture conditions.

The rotation consists of corn, oats and clover. The fertilizer experiment involves primarily a study of manure and crop residues supplemented by phosphates and potash in varying amounts. In

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TABLE 1.—*Showing climatological data and growth data for corn, seasons of 1918, 1919 and 1920.*

Month	1918				1919				1920			
	Rainfall		Temperature		Rainfall		Temperature		Rainfall		Temperature	
	Total	Departure	Mean	Departure	Total	Departure	Mean	Departure	Total	Departure	Mean	Departure
April	1.70	—0.10	40.8	—2.4	2.18	0.38	42.2	—1.0	2.36	0.56	35.8	—7.4
May	6.98	3.52	57.5	2.9	2.18	—1.28	54.9	0.3	4.44	0.98	55.6	1.0
June	0.48	—3.37	64.4	0.2	2.81	—1.04	68.6	4.4	6.57	2.72	62.9	—1.3
July	3.94	0.10	67.8	—0.9	6.40	2.56	70.0	1.3	4.53	0.69	65.0	—3.7
August	4.02	0.54	67.0	1.1	5.36	1.88	65.0	—0.9	1.39	—2.09	62.6	—3.3
Sept.	1.06	—2.03	51.6	—7.4	2.00	—1.12	59.2	0.2	2.47	—0.65	59.3	0.3
Total	18.21				20.93				21.76			
	Remarks:—Average corn season. Temperature near normal. Precipitation deficient in June.				*Remarks:*—Favorable corn season. Warm June and July. Precipitation well distributed.				*Remarks:*—Season unusually cool Abundant moisture except in August and September. Poor corn season.			
Average daily rate of growth—June 25 to July 19.	1.14 in.				2.45 in.				1.58 in.			
Date Planted Date Harvested	May 23. Sept. 15.				May 23. Sept. 8.				May 20. Sept. 3.			
	Fertilized Bu.		Unfertilized Bu.		Fertilized Bu.		Unfertilized Bu.		Fertilized Bu.		Unfertilized Bu.	
Yield per acre	46.90		43.13		72.10		65.33		19.59		18.53	

the following table is indicated the climatological data together with other information concerning the yield and rate of growth.

The yield of corn only is reported. It will be noted that in 1918 the average yield of all of the fertilized plots was 46.9 bushels per acre, while the unfertilized yielded about 3 bushels less. This is about the average yield of corn that may be expected on this soil type. The temperature during the important corn-growing months was nearly normal, though July was somewhat cooler than the average. June was a dry month and this is responsible for the yield not exceeding the average for soils of this type. The rate of growth from June 25 to date of tasseling, July 19, is a trifle over 1.1 inches per day.

The year 1919 was an especially favorable corn season. The temperature was considerably above the normal, especially during June. The rainfall was satisfactory and, what is also quite important, the distribution was ideal. The yield of the fertilized plots averaged 72.1 bushels per acre, while the unfertilized 65.33. Stimulated by the warm weather and ample moisture the daily growth was nearly 2½ inches. This abnormally high yield is attained on soil of this type when moisture and temperature conditions are ideal as illustrated in 1919.

The year 1920, on the other hand, was one of the poorest seasons on record. The average yield on the fertilized plots was less than 20 bushels per acre and about one bushel less for the unfertilized. The growing season was characterized by unusually cool weather, especially during June and July. The rainfall conditions were quite satisfactory, in fact every month, except August, showed above the normal rainfall. June and July are as a rule the important corn months. The distribution of rainfall during July was rather unsatisfactory, over one-half of the rainfall coming on the 13th. The cool weather, therefore, together with a rather unsatisfactory distribution of rainfall were primarily the causes for the low average yield of corn. The daily rate of growth, however, was satisfactory. Most of this growth was produced during June.

It is also interesting to note that the total rainfall for the six months shows but little variation from year to year. The distribution, however, varies quite widely. The average of the yield for the poorest year with that of the best (that is, 1919 and 1920) is about the normal crop, as represented by the year 1918.

THE RELATIVE VALUE OF THE ANNUAL WHITE, THE BIENNIAL WHITE, AND THE BIENNIAL YELLOW SWEET CLOVERS[1]

A. C. Arny and F. W. McGinnis[2]

INTRODUCTION

The wide spread attention given to the discovery and development of the annual white sweet clover has resulted in the expression of keen interest with regard to the merits of this clover in comparison with the biennial sweet clovers with which it is found to be in competition in some repects.

Until recently the limited amount of the annual white sweet clover seed available made it impossible for this plant to become established over any large area, or for its practical worth to be identified. Since this clover produces seed the same year that it is sown, it has been possible to develop rapidly and to extend greatly its use.

The value of the biennial sweet clovers has long been recognized, as they occupy a well defined place in the agriculture of the upper Mississippi Valley. Their use is chiefly as a pasture crop, altho in regions where they are well adapted they are grown to a considerable extent for hay and for green manuring purposes. Under certain conditions, the more rapidly growing annual white sweet clover is better suited to such uses than are the biennial sweet clovers.

Because of the growing interest in annual white sweet clover, a series of investigations have been conducted in Minnesota to learn more about the characteristic properties and behavior of this clover in comparison with the biennial white and the biennial yellow sweet clovers. Due to the fact that the sweet clovers are sensitive to acid soil conditions, and to a lesser degree, possibly, to climatic changes, the investigations were arranged to incorporate the wide range of environmental differences found in this state. A series of plot trials were laid down at the central station at University Farm, St. Paul, Minnesota, and also at the branch stations located at Crookston, Waseca and Duluth.

The chief points of interest in this investigation are the yields of forage, the quantities of roots remaining in the soil, and the ac-

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cumulation of nitrogen by each of the clovers. Nitrogen determinations were made on the forage, thus indicating the amount of nitrogen removed in the hay crop, or the amount returned to the soil when the crop is pastured or used for green manuring purposes. Nitrogen determinations were also made on the root material to indicate the amount accumulated in this way. The annual and biennial sweet clovers differ widely in this regard, as the data reported below indicate.

Entirely apart from the yielding power of the annual and biennial sweet clovers, there is the well known difference in plant habit of growth which makes the annual variety more desirable to sow in the spring, if the land must be plowed in the autumn of the same year.

PLAN OF EXPERIMENT

In 1921, a preliminary experiment was conducted at University Farm, St. Paul, and in 1922 the project was extended to include the branch stations as indicated above. In all cases, the sweet clovers were seeded at the rate of 12 pounds per acre, the seed being sown on well-prepared soil at grain planting time, on plots 132 x 8 feet in size. There were three plots of each seeding. The yields of forage were taken from the second cutting when the clovers were in full bloom. The unit was 6 square yards for each plot. The root yields were determined by taking all roots in two square yard areas in each plot to a depth of 12 inches. From these units, the yields are computed on the acre basis. Shrinkage samples on both top and root material were taken to serve in calculating the yields on the dry basis. The dry weight gives the actual organic material produced and makes possible the calculation of the acre yield of nitrogen. The percentage of nitrogen contained in the tops and root residues was determined for

TABLE 1.—*Comparison of annual white, biennial white and biennial yellow sweet clovers in yield of green material and dry matter per acre contained in the hay and the roots to a depth of 12 inches, together with the percentages of protein on the dry basis and pounds of protein per acre. University Farm, St. Paul, Minn., 1921.*

	No. of plants per sq. yd.	Yield per acre Green material Pounds	Green material Tons	Dry matter Pounds	Dry matter Tons	Protein Pounds per acre	Percentage of protein
Tops							
Annual white	142	8739	4.36	2375	1.18		
Biennial white	126	5297	2.64	1294	.64		
Biennial yellow	262	7717	3.85	2691	1.34		
Root residues							
Annual white	142	402	.20	243	.12	21.2	8.66
Biennial white	126	3724	1.86	1387	.69	322.6	23.10
Biennial yellow	262	5132	2.56	1874	.93	369.6	19.93

TABLE 2.—*Comparison of annual white, biennial white and biennial yellow sweet clovers in yields of green material and dry matter per acre contained in the tops and in the roots to a depth of 12 inches, together with percentages of protein and pounds of protein per acre. University Farm, St. Paul, Minn., 1922.*

	No. of plants per sq. yd.	Yield per acre Green material		Yield per acre Dry matter		Protein	Percentage of protein	Comparative yields on limed and unlimed soils Unlimed = 100 Dry matter	Protein
		Pounds	Tons	Pounds	Tons	Pounds			
Tops									
Annual white, no lime	90	2892	1.44	874	.44	113.6	13.00	100	100
Biennial white, no lime	271	4410	2.05	892	.44	179.1	19.41	100	100
Biennial yellow, no lime	207	2456	1.22	583	.29	120.9	20.18	100	100
Annual white, limed	151	6413	3.20	1860	.93	272.2	14.89	211	239
Biennial white, limed	193	4588	2.29	1523	.75	280.9	18.37	166	156
Biennial yellow, limed	191	4274	2.13	1317	.65	258.8	19.17	224	214
Root residues									
Annual white, no lime	90	357	.17	186	.09	13.2	7.03	100	100
Biennial white, no lime	271	2320	1.16	773	.38	143.0	18.47	100	100
Biennial yellow ,no lime	207	3088	1.54	1110	.57	220.6	19.93	100	100
Annual white, limed	151	501	.25	229	.11	21.0	9.23	122	159
Biennial white, limed	193	3168	1.58	1029	.51	205.5	19.98	134	143
Biennial yellow, limed	191	3254	1.62	1232	.61	253.0	20.58	107	114
Hay and root residues combined									
Annual white, no lime	90	3249	1.61	1060	.53	126.8		100	100
Biennial white, no lime	193	6430	3.21	1665	.82	322.1		100	100
Biennial yellow, no lime	207	5544	2.77	1693	.86	341.5		100	100
Annual white, limed	151	6914	3.45	2089	1.04	293.2		196	231
Biennial white, limed	271	7756	3.87	2552	1.26	486.4		153	151
Biennial yellow, limed	191	7528	3.76	2549	1.26	511.8		144	150

each plot, and for the convenience of discussion as well as to compare with former work, it was thought advisable to carry the nitrogen results in terms of protein (N×6.25).

Table 1 shows the summary of the preliminary results obtained at University Farm in 1921.

This test was carried out on a plat of land which had been in corn one year, following alfalfa. The soil was conducive to high yield and to a high percentage inoculation of the clovers. During the first year of growth, the top yield of the biennial yellow clover, on the dry basis, is 110 percent greater than that obtained from the biennial white. This difference is due largely to the lesser stand of the latter, as indicated by the number of plants per square yard. The stand of the biennial yellow is 107 percent greater than the biennial white, which must be considered to compensate for this yield difference. The annual white sweet clover, with a stand slightly more than one-half that of the biennial yellow, yielded 13 percent less than the latter.

The quantity of root residues of the biennial white sweet clover is 470 percent greater than that of the annual white. This is very significant in view of the fact that the top yield of the annual white is 84 percent greater than the biennial white sweet clover. An analysis of the data showing the amount of nitrogen left in the soil by root formation shows the annual white sweet clover to be far inferior to the biennials in performing this valuable function. This is due to the much lower yield of dry matter as well as the fact that the protein percentage is less than one-half that found in the biennials. The percentage of protein contained in the hay or top portion of the plant is nearly the same for the three sweet clovers. The protein percentage is a significant consideration if the roots only are to be depended upon to accumulate the organic nitrogen and the hay is to be removed as a forage. This preliminary experiment shows the protein collected and held in the roots to be 21.2 pounds per acre for the annual white, and 322.6 pounds and 396.6 pounds, respectively, for the biennial white and the biennial yellow sweet clovers.

Results at University Farm in 1922

In 1922, the more comprehensive plan was outlined to include the three branch stations as indicated above. At University Farm one-half of the entire series of sweet clover plats was limed at the rate of two tons per acre. The soil at University Farm is slightly acid in reaction and it seemed advisable, for comparative results, to determine the response the clovers would make under a condition generally accepted as more favorable to their growth. Since there appears to

be a difference in the effect of lime on the annual as compared with the biennial varieties as far as yields of dry matter and protein are concerned, the data are given for both the unlimed and the limed areas. These data are shown in Table 2.

Probably the most outstanding and important fact to be discovered from these data is the comparative yields of dry matter contained in the tops and root material of the three clovers on the limed and unlimed areas. The yields of tops, on the dry basis, from the limed area are 111 percent for the annual white sweet clover, 66 percent for the biennial white, and 124 percent for the biennial yellow greater than those from the unlimed areas. The amount of protein contained in the tops of these clovers is almost in proportion to the dry weight produced. The percentage of protein in the sweet clovers varies but slightly between the limed and unlimed soils; however, the percentage of protein in the annual white is approximately 5 percent lower than that of the biennials in both cases.

It would be reasonable to suppose that the root residues would make comparable gains on the limed soil, where the growth of these sweet clovers is greatly favored. The root deposits are increased under the limed condition; but this increase is not proportional to that obtained in the yields of tops. However, the yields of roots, on the dry basis, are 22 percent for the annual white, 34 percent for the biennial white, and 7 percent for the biennial yellow sweet clovers greater than those from the unlimed soils. The percentage of protein contained in the roots, unlike that for the tops, is consistently greater in the material from the limed soil. This difference is slight; but this factor, combined with the marked increase in dry matter production, produces a much higher nitrogen deposit in the soil on the limed area.

By assembling the dry matter weights of the tops and the roots to indicate the complete yields of the three sweet clovers on limed and unlimed soils, the adaptability of soils at University Farm for the growth of sweet clovers is made clear. The total weight of the annual white sweet clover is 96 percent, the biennial white 53 percent, and the biennial yellow 44 percent greater on the limed than on the unlimed area. The acre yield of nitrogen varies from 50 percent gain in the biennials to 130 percent gain in the annual white on the limed soil above that on the unlimed.

Comparative Yields of Sweet Clover Hay at University Farm, Crookston Waseca, and Duluth

From the data presented above it is quite obvious that for the successful growth of sweet clovers at University Farm, it is necessary

to use a comparatively heavy application of lime to obtain satisfactory results. Hence, in studying the comparative performance of the sweet clovers at the different stations it is thought advisable to use only the data from the limed soil at University Farm, as this represents more nearly a normal growth condition.

Table 3 shows the yields of green and dry weight of tops obtained from the annual white, biennial white and biennial yellow sweet clovers, grown at University Farm, Waseca, Crookston and Duluth. At Waseca, the sweet clover was grown on unlimed land. Somewhat larger yields of sweet clover are secured on limed than on unlimed land at Waseca. At Crookston applications of lime are not essential for the best growth of sweet clover. Lime had been applied to the land on which the sweet clover was grown at Duluth.

For convenience in discussion, the comparative yields of tops of the sweet clovers have been interpreted in terms of percentage. At all stations the yield of annual white sweet clover is represented by 100. Deviation from this is expressed in percentage differences. Also, to make clear the comparative yields of the clovers at the different stations, the results obtained at University Farm in each case are represented by 100.

The yield of the annual white sweet clover tops, on the dry basis, is approximately 15 percent greater than that of the biennial white and 35 percent greater than that of the biennial yellow as an average of the trials at the four stations. While the clovers do not yield alike at the different stations, in each case the annual white produces the largest top yield and the biennial yellow the lowest. On the limed soil at University Farm and at Crookston and Waseca where the soil and climatic conditions are conducive to rapid growth, the annual white sweet clover exceeds the biennials, especially the biennial yellow, in yield of hay. At Duluth, where environmental conditions are less favorable for rapid growth and high yields, the annual white sweet clover outyields the biennials by a very small margin. It would seem that the comparative yields of hay of the annual and the biennial sweet clovers are dependent to a considerable extent upon the seasonal environment.

The average yields of tops of the three sweet clovers at Crookston are 53 percent greater than the average at University Farm. The yields at Waseca are 47 percent greater than those at University Farm, while the results from Duluth show the annual white and biennial white sweet clovers to be slightly less. The yield of biennial yellow sweet clover is a little higher than at University Farm.

Table 3.—*Yields of green material and dry matter of tops of annual white, biennial white and biennial yellow sweet clovers grown at University Farm, Waseca, Crookston and Duluth, Minn., 1922.*

	University Farm		Waseca		Crookston		Duluth	
	Pounds	Tons	Pounds	Tons	Pounds	Tons	Pounds	Tons
Green Material								
Annual white	6413	3.20	5367	2.68	6723	3.36	4968	2.48
Biennial white	4588	2.29	5390	2.69	7350	3.66	4412	2.20
Biennial yellow	4274	2.13	2778	1.39	3675	1.83	3914	1.95
Dry matter								
Annual white	1860	.93	3596	1.79	2832	1.41	1554	.77
Biennial white	1523	.75	2203	1.10	2775	1.38	1454	.72
Biennial yellow	1317	.65	1366	.68	1669	.83	1418	.70

Comparative yields of tops on the dry matter basis.

	University Farm yields as 100				Annual white as 100			
	University Farm	Waseca	Crookston	Duluth	University Farm	Waseca	Crookston	Duluth
Annual white	100	193	152	83	100	100	100	100
Biennial white	100	144	182	95	82	61	98	94
Biennial yellow	100	104	126	107	70	35	58	91

Table 4.—*Yields of root residues in green material and dry matter of annual white, biennial white and biennial yellow sweet clover grown at University Farm, Waseca, Crookston, and Duluth, Minn., 1922.*

	University Farm		Waseca		Crookston		Duluth	
	Pounds	Tons	Pounds	Tons	Pounds	Tons	Pounds	Tons
Green material								
Annual white	501	.25	928	.46	3719	1.85	2713	1.35
Biennial white	3168	1.58	8352	4.67	6566	3.28	3474	1.73
Biennial yellow	3254	1.62	9938	4.96	7037	3.51	4082	2.04
Dry matter								
Annual white	229	.11	282	.14	1088	.54	595	.29
Biennial white	1029	.51	2936	1.46	1783	.89	774	.38
Biennial yellow	1232	.61	3675	1.83	2241	1.11	1101	.55

Comparative yields of roots on the dry basis.

	University Farm yields as 100				Annual white as 100			
	University Farm	Waseca	Crookston	Duluth	University Farm	Waseca	Crookston	Duluth
Annual white	100	123	477	260	100	100	100	100
Biennial white	100	285	173	75	463	1042	164	130
Biennial yellow	100	298	181	90	554	1307	206	185

The most important conclusion to be drawn from the data showing the top yields of the sweet clovers, determined the same year as they were sown, is that the annual white exceeded the biennial white by approximately 15% and the biennial yellow by 35%. In all cases, the biennial white outyields the biennial yellow; but this difference is not as great as that between the annual and the biennial white.

Although no data concerning yields of tops from the biennial clovers in the second year from seeding are presented, it is reasonable to assume that the yields of tops from the biennials in two crops during the second year would be larger than that from the annual grown the same year.

It would be expected that the root residue of these clovers should be in proportion to the yield of tops; but upon studying the data for the yields of roots, the reverse order is found to prevail. The sweet clover producing the largest top yield deposits the lowest yield of root residue.

Comparative Yields of Root Residues at University Farm, Waseca, Crookston and Duluth

The yields of root residues from each of the clovers at each of the four stations are shown in Table 4. In each trial, the root residue is greatest from the biennial yellow sweet clover. The biennial white produces from 25 to 50 percent less, while the annual white yields only a small fraction of the biennial deposits. The weight of root residues of the annual white sweet clover at Waseca is less than one-tenth of the average for the biennials. The difference is large at University Farm, where the annual white deposits approximately one-fifth the amount left by the biennials; while at Crookston and Duluth the biennial root yields are not twice as much as the annual white. There appears to be a very much wider variation in the production of the root systems of the sweet clovers at the different stations than there is of the top portions of the plants. A satisfactory explanation for the wide variations in the root yields at the different stations cannot be found from a study of the records of climatic changes. It is probable that a soil environment conducive to rapid growth has a tendency to increase the proportion of yields of roots of the annual white sweet clover as compared with the biennials, in an order which is inverse to that of the yields of hay.

No determinations of dry matter in the biennial roots the second season from planting were made. The data secured from the first year of growth indicate that the dry matter in the roots of two crops of the annual white could scarcely equal that laid down in the roots of the biennials during the first season of growth.

TABLE 5.—*Yields of top and root residue combined in green material and dry matter of annual white, biennial white and biennial yellow sweet clovers grown at University Farm, Waseca, Crookston and Duluth, Minnesota, 1922.*

	University Farm		Waseca		Crookston		Duluth	
	Pounds	Tons	Pounds	Tons	Pounds	Tons	Pounds	Tons
Green material								
Annual white	6914	3.45	6295	3.14	10442	5.22	7681	3.83
Biennial white	7756	3.87	13742	6.87	13916	6.95	7886	3.93
Biennial yellow	7528	3.76	12716	6.35	10712	5.35	7996	3.99
Dry matter								
Annual white	2089	1.04	3878	1.93	3920	1.96	2150	1.06
Biennial white	2552	1.26	5139	2.56	4558	2.27	2228	1.11
Biennial yellow	2549	1.26	5041	2.51	3910	1.95	2519	1.25

Comparative yields of dry matter in tops and root residues combined

	University Farm yields as 100				Annual white as 100			
	University Farm	Waseca	Crookston	Duluth	University Farm	Waseca	Crookston	Duluth
Annual white	100	185	187	103	100	100	100	100
Biennial white	100	201	178	87	122	132	116	103
Biennial yellow	100	197	153	98	121	130	99	117

TABLE 6.—*Percentage of protein contained in the top and root material of the annual white, biennial white, and biennial yellow sweet clovers grown at University Farm, Waseca, Crookston, and Duluth, Minnesota, 1922.*

	Percentage of protein in tops				Percentage of protein in roots			
	University Farm	Waseca	Crookston	Duluth	University Farm	Waseca	Crookston	Duluth
Annual white	14.89	13.01	14.27	16.34	9.23	8.59	6.59	9.34
Biennial white	18.37	15.67	15.61	17.50	19.98	21.12	14.09	16.14
Biennial yellow	19.17	16.42	13.70	17.83	20.58	21.94	14.70	18.17

In order to have a record showing the complete performance of each of the clovers at the different stations, the data for top and root yields are assembled in Table 5. This will make more definite the comparison between them.

There is no consistent difference between the yields of the biennial white and biennial yellow sweet clovers when the entire plant, tops and roots, is used as the measure. At University Farm and Waseca, the biennial white and biennial yellow yield practically the same. At Crookston, the biennial white outyields the biennial yellow by 15 percent. Averaging the results of total production at the four stations, the biennial sweet clovers yield a total dry weight of approximately 25 percent more than the annual white sweet clover.

The suitability of the regions for sweet clover production is made clear by a study of the summary of the above table. The average yield of the top and root material of all the sweet clovers at Crookston is approximately 75 percent greater than at University Farm. The total yield at Waseca is 94 percent greater, while at Duluth their yield is 12 percent less than at University Farm.

Percentage of Protein Contained in the Top and Root Material

In order to estimate the amount of nitrogen accumulated per acre, it is necessary to determine the percentage of nitrogen in the top and root material. Table 6 shows the differences in protein percentages ($N \times 6.25$) in the clovers at each station.

As an average for the four stations, the percentage of protein contained in the tops is the same in the two biennial sweet clovers. The biennial sweet clovers carry 16.79 percent protein and the annual white contains 14.65 percent. The percentage of protein contained in the root material of the biennial white and biennial yellow sweet clovers, like that of the top portion, is approximately the same; but the annual white root material contains less than one-half that found in the biennials. The biennial roots contains 18.34 percent protein and the annual white 8.44 percent. This is very significant in affecting the acre yield of nitrogen deposited.

The effect of the percentage of protein as related to the total acre yield of nitrogen can be determined by computing the pounds of protein produced per acre from the top and root material for each of the sweet clovers at the different stations. Table 7 shows the accumulation of protein in the top and root material for each of the sweet clovers.

As the percentage of protein in the tops of the biennial sweet clovers at each station is very nearly identical, the acre yield of protein is

TABLE 7.—*Yield of protein in pounds per acre in the top and root residue of annual white, biennial white and biennial yellow sweet clovers grown at University Farm, Waseca, Crookston, and Duluth, 1922.*

	Annual white sweet clover			Biennial white sweet clover			Biennial yellow sweet clover		
	Tops	Roots	Total	Tops	Roots	Total	Tops	Roots	Total
University Farm	272.2	21.0	293.2	280.9	205.5	486.4	258.8	253.0	511.8
Waseca	469.0	23.8	492.6	344.5	607.2	951.7	219.0	805.7	1024.7
Crookston	404.7	71.5	476.2	438.0	254.3	692.3	228.0	327.3	555.3
Duluth	252.8	49.8	302.6	255.6	124.8	380.4	252.0	197.4	450.1
	Comparative production of nitrogen, University Farm as 100.								
	Annual White			Biennial White			Biennial Yellow		
University Farm	100	100	100	100	100	100	100	100	100
Waseca	172	113	168	123	295	196	84	318	201
Crookston	147	340	164	156	124	142	88	129	108
Duluth	92	237	103	91	61	78	97	78	87
	Comparative production of nitrogen, annual white as 100								
University Farm	100	100	100	103	978	165	95	1204	174
Waseca	100	100	100	73	2551	193	47	3385	208
Crookston	100	100	100	108	355	145	56	457	116
Duluth	100	100	100	101	250	125	100	396	148

in proportion to the dry matter produced. The percentage of protein in the annual white is somewhat lower than that contained in the biennials, but, due to the higher production of dry matter, the accumulation of protein in this plant is the same as in the biennial white, but 25 percent greater than is found in the biennial yellow sweet clover. Due to the fact that the annual white sweet clover roots contain less than one-half the protein percentage that is contained in the biennials and that the yield of dry matter of the latter is five to seven times as great, the collection of nitrogen in the roots of the annual white sweet clover is only approximately one-tenth as much as is contained in the biennial white and one-fourteenth as much as is found in the biennial yellow sweet clovers.

The total production of protein in the tops and roots is 55 percent greater in the biennial white and 61 percent greater in the biennial yellow sweet clovers than that contained in the annual white sweet clover plant.

SUMMARY

The results secured under the conditions prevailing in the sections of the state where the trials were made may be summarized as follows:

A preliminary trial, in 1921, gave yields in dry matter of tops for the annual and biennial varieties approximately equal; but yields in dry matter of roots very greatly in favor of the biennials. The protein percentage in the roots of the biennials was also much higher than in the annual variety.

The results at University Farm in 1922 confirm the results obtained in 1921 and further indicate that, on soils deficient in lime for the sweet clover crop, all the varieties were materially benefited by applications of lime, the annual variety apparently being benefited to a greater extent than the biennial varieties.

As an average for the trials at four stations in 1922, the annual white variety yields 15 percent more dry matter in the tops than the biennial white and 35 percent more than the biennial yellow variety. On the heavier soils at Waseca and Crookston, the yields of dry matter in the tops were larger than at University Farm, where the subsoil is a gravel. At Duluth, the yields of tops were equal to those at University Farm.

The percentages of protein in the tops of the three varieties were approximately equal.

The annual white variety produced larger yields of tops but lower yields of roots than the biennials. There was greater variation in the dry matter yields from the roots than from the tops.

The amount of dry matter in both tops and roots is (with one ex-

ception) considerably in favor of the biennial varieties. On the average, there is approximately a 25 percent advantage in favor of the biennials in this respect.

The percentages of protein in the roots of the annual white variety were uniformly lower than the percentages in the roots of the biennials. The average for the annual is 8.44% and for the biennials 18.34%.

The total production of protein in the tops and roots is 55 percent greater in the biennial white and 61 percent greater in the biennial yellow sweet clovers than in the annual white variety.

Where an annual hay crop is desired and the effect on the land is a secondary consideration, the greater yield of hay or of pasturage in the same season that it is sown should establish a use for the annual white variety, provided seed is produced in such quantities that the cost for seed is not higher than the seed cost of other crops that may be used for this purpose.

AN INQUIRY INTO THE REASON FOR THE LARGE ACCUMULATION OF NITRATES IN SOIL FOLLOWING THE GROWTH OF CLOVER OR ALFALFA[1]

T. L. LYON, J. A. BIZZELL, AND B. D. WILSON[2]

The beneficial effect of the growth of clover on the productiveness of soil is common to almost all regions. Even when the hay is removed and only the stubble and roots are incorporated in the soil the effect on succeeding crops may usually be noted, except where nitrogen is not the limiting factor in plant growth. It is rather common to assume that this property of the clover plant is due to the store of nitrogen which it lays up in the soil, as the result of its fixation of that element from the atmosphere. While there may usually be an increase in the nitrogen content of soil resulting from the growth of clover or alfalfa, such is not always the case, as has been definitely shown by Swanson (1)[3] and indicated by the experiments of Lyon and Bizzell (2). In spite of the fact that there appeared to be little or no more total nitrogen in the soil on which alfalfa had grown for six years than in that on which timothy had grown for the same length of time, the nitrate nitrogen was found, by Lyon and Bizzell (3), to be more abundant following a crop of alfalfa than following timothy.

It was with the purpose of attempting to determine why nitrate nitrogen is more abundant in a soil following the growth of clover

[1]Contribution from the Department of Agronomy, Cornell University, Ithaca, New York. Received for publication April 24, 1924.

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[3]Reference by number is to "Literature Cited," p. 405.

than of timothy that these experiments were begun. A preliminary report (4) was published in 1919. This contained a review of the literature dealing with (1) the capacity of a soil to form nitrates from the nitrogen remaining after the growth of certain legumes, and (2) the power of the soil to form nitrates from nitrogenous organic matter or ammonium salts when brought into the laboratory and incubated.

It will not be necessary to make any further references to the literature of the subject nor to review the preliminary report. The following paper deals only with those experiments which were conducted after the preliminary report was made. The special apparatus consisting of cans or cylinders mounted on trucks in which the plants were grown and in which the soil was leached are described in the previous paper.

THE EXPERIMENTS

The cans having been heavily leached after removing the oats and maize grown in the summer of 1918, the soil was removed from each can to a depth of twelve inches and after the large roots were removed the soil was mixed with the following materials:

80 grams ground limestone = 4000 lbs. per 3,000,000 lbs. soil.
40 grams dried blood = 2000 lbs. per 3,000,000 lbs. soil.
10 grams acid phosphate = 500 lbs. per 3,000,000 lbs. soil.
5 grams muriate of potash = 250 lbs. per 3,000,000 lbs. soil.

The soil was then returned to the can from which it had been removed for mixing with the fertilizers. Cans 9 to 14 inclusive were planted with red clover and cans 15 to 20 inclusive were planted with timothy seed. It will be noticed that cans previously in timothy were now in red clover and vice versa.

Both the clover and timothy made a good growth (see Figure 1) and three crops of each were cut. The nitrogen in the red clover amounted to 8.37 grams for each can in the three cuttings, while the timothy produced 2.43 grams of nitrogen in the same number of cuttings. It may be noted that the timothy only developed heads once, the other cuttings being made merely because the clover was ready to cut. During the time that these crops were on the soil, which was from March to December, the cans were leached eight times. These leachings removed an average of 203.2 mg. of nitrogen from each of the red clover cans and 39.8 mg. from each of the timothy cans. Timothy plants and the leachings combined had removed from the soil, up to this point in the experiment, something more than one-half the nitrogen added in the form of dried blood.

It was now of interest to ascertain whether the effect of either crop

is to increase or diminish nitrate accumulation following its removal from the soil in spite of the large quantity of easily nitrifiable nitrogen

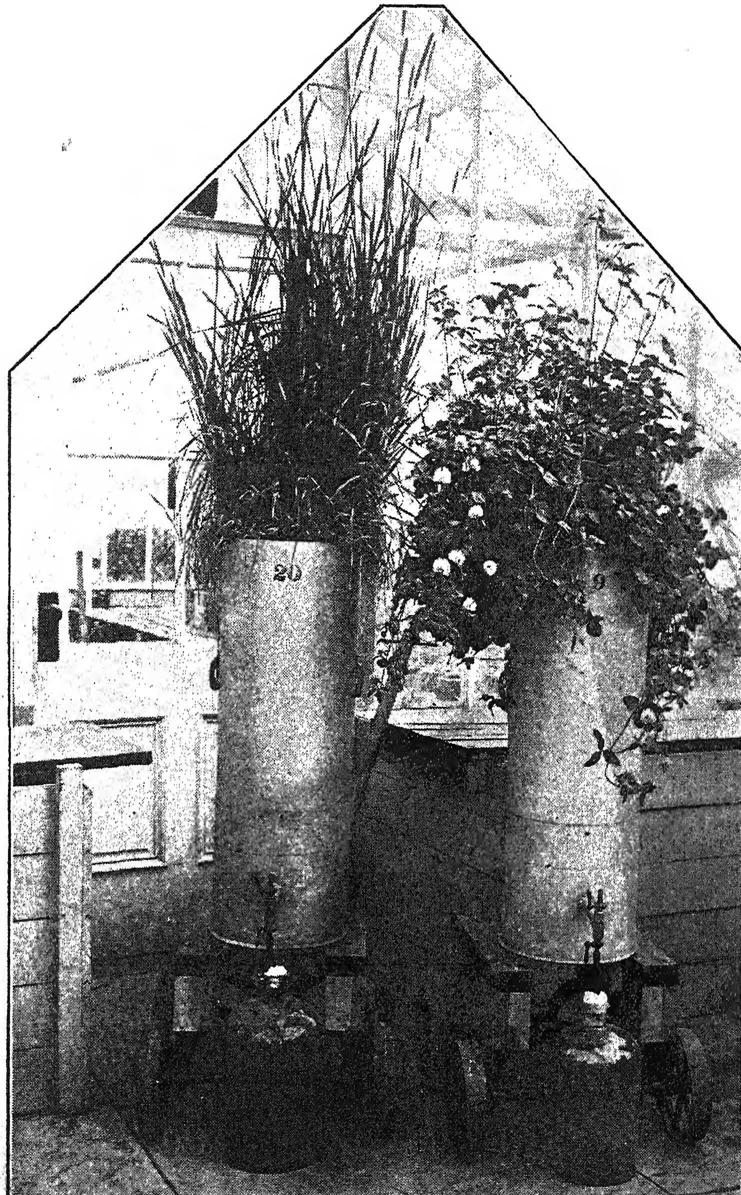

FIG. 1. Representative cans of timothy plants and clover plants at time of first cutting.

present in the form of dried blood in the timothy soil and presumably in the clover soil if it is assumed that the crop obtained most of its nitrogen from the air.

NITROGEN IN DRAINAGE WATER FOLLOWING RED CLOVER AND TIMOTHY

After harvesting the clover and timothy the soil was stirred to a depth of about 2 inches and the stubble was removed, but the roots were left in the soil. The soil from cans 12–14 and 18–20 was then removed to the depth of the clay subsoil. It was then passed thru a quarter-inch mesh sieve to remove plant roots.

When the clover and the timothy roots were removed from the soil they were cleaned by brushing and were then weighed. The soil could not be sufficiently well removed from the roots to allow of accurate determinations but roughly the weights were as follows:

	Clover roots		Timothy roots
Can 12	113.0 grams	Can 18	232.5 grams
Can 13	81.0 grams	Can 19	345.5 grams
Can 14	89.5 grams	Can 20	349.0 grams
Total	283.5 grams	Total	927.0 grams

The larger weight of the timothy roots was because of their much greater number. The individual clover roots were larger than those of the timothy.

The soil in cans 9–11 and 15–17 was not removed, but was kept at optimum moisture content for three weeks without planting for cropping, after which it was leached. From the date of this first leaching, which was February 6, until April 19, each can was leached seven times. During this entire period the soil in all the cans was kept free of vegetation. The nitrate nitrogen in the leachings was determined, with the results shown in Table 1.

TABLE 1.—*Nitrogen (in grams) in leachings from soil previously in red clover and soil previously in timothy.*

Date of incubating Jan. 17 Date of leaching	Previous crop Clover Cans 9–11	 Timothy Cans 15–17
Feb. 6	0.256	0.054
Feb. 9	0.174	0.029
Mar. 2	0.384	0.208
Mar. 17	0.433	0.284
Apr. 7	0.482	0.357
Apr. 12	0.279	0.268
Apr. 19	0.165	0.170
Total	2.173	1.370

As in the experiment previously reported, more nitrates were found following the growth of clover than after timothy. There would seem

to be several possible explanations to account for the greater accumulation of nitrates in the clover soil; (1) the plant residues remaining in the clover soil may be more easily nitrified than is dried blood, (2) the clover plant may produce a substance that stimulates nitrate formation, (3) the timothy plant may produce a substance that retards nitrate formation or nitrate accumulation.

DISCUSSION

In the preliminary report of this experiment, the possibility of the clover leaving in the soil a residue more readily nitrifiable than dried blood was mentioned. A comparison of the relative nitrifiability of dried blood and finely ground roots was made in subsequent experiments and the results reported elsewhere (5). They did not indicate that clover roots are more readily nitrifiable than is dried blood; and while some of the smaller roots and some of the nodules were doubtless lost in removing the roots this would be at least partially offset by the grinding that the roots received. The much greater accumulation of nitrate from dried blood in the experiment cited, amounting to nearly twice as much nitrate nitrogen from the same quantity of organic nitrogen in the two substances, would give little reason to conclude that clover roots nitrify more readily than dried blood.

It was also suggested that clover might leave as a residue a substance that stimulates nitrate formation or that timothy might in a similar way retard nitrate accumulation. The experiments with the ground roots, which have just been referred to, suggest very strongly that timothy roots have a depressing effect on nitrate accumulation and as the depressing action of the various roots was in the inverse order to their nitrogen content it seemed likely that the non-nitrogenous organic matter was concerned with this property, which it might possibly influence by encouraging the growth of the nitrate nitrogen consuming organisms in the soil.

The phenomena in these experiments seem to fit rather well with the hypothesis that the depression of nitrate accumulation is due to the development of nitrate-nitrogen-consuming organisms, made possible by the presence of available energy material, the supply of which is sufficiently influenced by plant residues to cause the soil to show differences in nitrate nitrogen content, traceable to the clover or timothy that previously occupied the soil. The timothy residues being richer in carbonaceous matter than those of clover, nitrate accumulation is curtailed by nitrate-nitrogen-consuming organisms and, therefore, it progresses more rapidly and reaches a higher figure

in soil following the growth of clover than of timothy. This is true whether the content of total nitrogen is greater in the clover soil or not and even when dried blood, a readily available supply of nitrogen, is present.

It has already been suggested by Doryland (6), and later by Hutchinson (7), both of whom studied the effect of certain carbohydrates on nitrate accumulation in soil, that the presence of more or less of these carbohydrates in plant residues or in green manure crops may influence the accumulation of nitrates in soil with which they are incorporated. These predictions appear to be supported by the results of the experiments just described.

THE PROPORTION OF TOTAL SOIL NITROGEN IN THE FORM OF NITRATE NITROGEN FOLLOWING ALFALFA AND TIMOTHY

An example of the influence of alfalfa as compared with timothy on the accumulation of nitrate nitrogen in soil occurs on certain plats on Caldwell Field. These plats are in two different crop rotations one of which consists of maize, one year; oats, one year; followed by alfalfa for three years: the other of maize, oats, and timothy, the latter for three years. These rotations have been followed since 1911. There are ten plats in each rotation, of which two are in maize each year, two in oats and six in the hay crop. No fertilizer or manure has ever been applied, but all plats have been limed to insure a good growth of alfalfa. Plats in the timothy rotation received the same lime treatments as did those in the alfalfa rotation.

The plats were all sampled from time to time to a depth of 8 inches and total nitrogen determined. Samples were last taken in 1920 and the figures for this analysis are used in the calculations which follow. Each year, from 1916 to 1923 inclusive, all the plats in maize were sampled to a depth of 8 inches before the maize plants were 12 inches high. At this time, the plants were not large enough to affect greatly the nitrate content of the soil between the rows. In the eight years during which this sampling has been conducted, each plat has been sampled at least once.

The data which are now at hand include total nitrogen and nitrate nitrogen for each plat. These may be grouped for the alfalfa plats and for the timothy plats and the average total nitrogen and nitrate nitrogen found for each cropping system. The figures so obtained are presented in Table 2.

Assuming that an acre of soil to a depth of eight inches weighs 2,500,000 pounds, there would be 3,550 pounds per acre of total nitrogen and 252.4 pounds of NO_3 in the alfalfa soil and 2,150 pounds

Table 2.—*Showing the total soil nitrogen in each of the ten plats planted to alfalfa and the same for each of the plats planted to timothy and the nitrates for the same plats, two of which were sampled each year from 1916 to 1923 inclusive.*

	Alfalfa soil	Timothy soil			Alfalfa soil			Timothy soil	
Plat No.	Total nitrogen Percent	Plat No.	Total nitrogen Percent	Year Sampled	Plat No.	Nitrates (NO_3) p. p. m.	Year Sampled	Plat No.	Nitrates (NO_3) p. p. m.
2001	.149	2011	.137	1916	2001	81.7	1916	2011	45.7
2002	.140	2012	.132	1917	2002	108.0	1917	2012	65.1
2003	.129	2013	.126	1918	2003	71.5	1918	2013	73.7
2004	.142	2014	.129	1919	2004	76.8	1919	2014	75.4
2005	.154	2015	.126	1920	2005	115.2	1920	2015	77.4
2006	.143	2101	.124	1916	2006	105.3	1916	2101	55.1
2007	.146	2102	.121	1917	2007	81.6	1917	2102	39.9
2008	.143	2103	.108	1918	2008	88.6	1918	2103	63.9
2009	.148	2104	.124	1919	2009	79.3	1919	2104	48.3
2010	.126	2105	.136	1920	2010	113.4	1920	2105	83.2
				1921	2001	176.0	1921	2011	91.7
				1922	2002	93.8	1922	2012	90.8
				1923	2003	116.6	1923	2013	50.0
				1921	2006	105.6	1921	2101	54.0
				1922	2007	93.8	1922	2102	39.6
				1923	2008	108.0	1923	2103	50.4
Average	.142		.126			100.9			62.8

of total nitrogen and 156.9 pounds of NO_3 in the timothy soil. From these figures, it may be calculated that for every 100 pounds of total nitrogen the alfalfa soil contains 7.11 pounds of NO_3 and for the same amount of total nitrogen the timothy soil contains 4.99 pounds of NO_3. These data are shown in Table 3.

TABLE 3.—*Total nitrogen and NO_3 in alfalfa and timothy soil.*
(Expressed in pounds to the acre)

	Total Nitrogen	Nitrates (NO_3)	Pounds NO_3 for every 100 lbs. total nitrogen
Alfalfa soil	3,550	252.4	7.11
Timothy soil	3,150	156.9	4.99

The effect of the alfalfa residues, when plowed under, was to produce a larger accumulation of nitrate in proportion to the total nitrogen content than did the timothy residues. This supports the conclusion from the previous experiment, to the effect that the greater quantity of available nitrogen in a soil following the growth of clover as compared with timothy may or may not be due in part to the larger quantity of total nitrogen in the clover soil; but, in any case, the nature of the crop residues is the main factor in determining the accumulation of nitrates.

The fact that nitrate accumulation is greater in alfalfa soil than in timothy soil would account for the failure of alfalfa when grown for a considerable number of years, to leave in the soil a higher nitrogen content than did prairie grass, in Swanson's observations mentioned above, or timothy, in those of Lyon and Bizzell. Where nitrification is abundant, the alfalfa crop makes use of nitrate nitrogen; and, owing to its large demands for that element, the total nitrogen content of the soil is prevented from increasing indefinitely. On the other hand, the deposition of energy-producing material by the timothy crop is probably rather favorable to the fixation of nitrogen by non-symbiotic organisms.

SUMMARY

(Including results of some previous work)

Soil on which alfalfa grew for six years contained little or no more total nitrogen than did soil on which timothy grew for the same length of time.

When allowed to incubate both in the field and in the laboratory, there was a greater accumulation of nitrates in the alfalfa soil.

Soil containing a very large quantity of dried blood and in addition residues of clover and timothy, respectively, accumulated nitrates in the same relative order as when no dried blood was present.

Experiments in which dried blood, ground clover roots, and ground timothy roots were each incorporated in soil placed in different receptacles and the nitrates determined after incubation, showed that the soil containing dried blood accumulated nearly twice as much nitrate nitrogen as did the clover soil and four times as much as did the timothy soil. From this, we conclude that the rate of nitrate accumulation in soil is influenced by the nature of the decomposing crop residues even when the main supply of nitrogen is in a more easily nitrifiable form than are the crop residues.

Crop growth, both in the field and in the greenhouse, was greater following alfalfa or clover than following timothy, whenever available nitrogen was the limiting factor. This was true even when such quantities of dried blood had been applied as would have made the nitrogen supply entirely sufficient to produce the subsequent crops without calling on the residues from the clover and timothy. These plant residues affected plant growth in the same way that they did nitrate accumulation.

The nature of the residues of the preceding crop may, therefore, be expected to affect the availability of a nitrogenous fertilizer, at least if it is an organic substance, and in all probability even a nitrate fertilizer would be affected to some extent.

Land that had been planted to a crop rotation in which alfalfa grew for three years and grain two years, contained a larger proportion of its total nitrogen in the form of nitrate than did land that carried a crop rotation in which timothy grew for three years and grain crops for two years.

CONCLUSIONS

The rapid and large accumulation of nitrates in soil previously planted to clover or alfalfa, as compared with soil previously in timothy, appears to be connected with the higher nitrogen content of the former. It is not necessarily associated with a larger total quantity of nitrogen in the legume soil, but rather with its smaller quantity of non-nitrogenous organic matter (probably carbohydrates). It is well known that non-nitrogenous organic matter furnishes a source of energy for the organisms which transform the nitrogen of soil nitrates into other nitrogen compounds. This source of energy being present in smaller quantity in the residues of these legumes than in the residue from timothy, there is less destruction of nitrates in soil previously planted to clover or alfalfa than in soil previously in timothy. It seems also probable that this may be a factor in determining the effect which other crop residues exert on nitrate ac-

cumulation and thus on the supply of available nitrogen for succeeding crops.

REFERENCES CITED

1. SWANSON, C. O. The effect of prolonged growing of alfalfa on the nitrogen content of the soil. *In* Jour. Am. Soc. Agron. 9:305–314. 1917.
——— and LATSHAW, W. L. Effect of alfalfa on the fertility elements of the soil in comparison with grain crops. *In* Soil Sci. 8:1–39. 1919.
2. LYON, T. L., and BIZZELL, J. A. Some relations of certain higher plants to the formation of nitrates in soils. Cornell University Agr. Exp. Sta. Mem. 1. 1913.
3. LYON, T. L., and BIZZELL, J. A. The influence of alfalfa and of timothy on the production of nitrates in soils. *In* Centr. Bakt. II Abt. Bd. 37:161–167. 1913.
4. LYON, T. L., BIZZELL, J. A. and WILSON, B. D. The formation of nitrates in a soil following the growth of red clover and of timothy. *In* Soil Sci. 9:53–64. 1920.
5. LYON, T. L., BIZZELL, J. A. and WILSON, B. D. Depressive influence of certain higher plants on the accumulation of nitrates in soil. *In* Jour. Am. Soc. Agron. 15:457–467. 1923.
6. DORYLAND, C. J. T. The influence of energy material upon the relation of soil microorganisms to soluble plant food. N. D. Exp. Sta. Bul. 116. 1916.
7. HUTCHISON, H. B. The influence of plant residues on nitrogen fixation and on losses of nitrates in the soil. *In* Jour. Agr. Sci. 9:92–111. 1918.

BOOK REVIEWS

MANURING GRASS LAND FOR HAY

By Winifred E. Brenchley. Rothamsted Experiment Station. Longman's Greene and Company. London and New York. Pp. vi + 144, fig. 22, tables vi, 1923.

This monograph includes the results from various manurial experiments on permanent grassland, which have been carried on continuously at Rothamsted since 1856. Special attention is given to the effect of liming superimposed upon the original manuring.

The total yield of hay, various species and the plant associations are tabulated for each treatment. As all the data are in semi-tabular form, it is very easy to make comparisons with earlier results, and to note the changes in the vegetation induced by manuring during the experimental period.

The effect of manuring and lime on the total herbage and on the individual species are treated separately, which facilitates a study of the total yield or the ecological relations for each manurial treatment. One of the outstanding effects is the depression of yields by liming on a number of the plots, especially some of those treated with sodium nitrate. Only the plots treated with ammonium sulphate showed a positive permanent response to lime.

The monograph deals solely with the Rothamstead plots and no attempt is made to compare it with other work. A very comprehensive report of the herbage is given for each manurial treatment, making the book of greatest interest to the ecologist and those interested in experimental work on permanent grassland. (H. P. Cooper.)

VOCATIONAL EDUCATION IN FARMING OCCUPATIONS

By Theodore H. Eaton. Philadelphia: J. B. Lippincott Co., 374 pp. 1923. $2.00.

"Every state in the union now has organized into its system of formal education a program of vocational education in agriculture. The influence of the Federal Act for Vocational Education, passed in 1917, has tended to give such programs common elements of likeness." Theodore H. Eaton, in his book *Vocational Education in Farming Occupations*, deals with the "philosophy of social organization contributing to the achievement of that purpose" implied in such programs.

He gives a comprehensive and satisfactory treatment of the field, beginning with a consideration of the social and psychological bases in vocational education and argues for formal education in agriculture. This argument is based on the following six factors: (a) The changed significance of physical factors; (b) the changed conception of social progress; (c) the changed demands of society upon agriculture; (d) the changed needs of the agriculturist; (e) the unchanged nature of man; (f) the break-down of agencies.

He takes up such practical considerations as the agencies for this sort of education, the necessary equipment, the length of terms, the school day, and work. His criteria for the selection of content are (1) "demands of vocation," (2) "educative environment," (3) "the characteristics of the learner," and (4) the need for training the student to take his proper place in the social community. He next classifies the various forms of teaching in vocational agriculture into (1) "supervised work on farms," (2) "directed farm studies," (3) "construction and repair," (4) "laboratory work." This portion of the book, together with the concluding sections on general problems of school method is of special value to teachers in this field.

The entire book is one to appeal to the general reader interested in social and educational problems, as well as to the specialist. (Helen W. Bateman.)

AGRONOMIC AFFAIRS

NOTES AND NEWS

Earl N. Bressman, formerly Assistant Agronomist at the Montana Agricultural Experiment Station became Professor of Agronomy in the College and Associate Agronomist of the Experiment Station at Corvallis, Oregon, on January 1, 1924.

S. C. Vandecaveye, formerly of the Department of Soil Bacteriology at Iowa State College is now Bacteriologist of the Agricultural Experiment Station at Pullman, Washington.

H. A. Huston has severed his connection with the Potash Importing Corporation and is now engaged in consulting work, with headquarters at Kew Gardens, Long Island, N. Y.

Dr. J. G. Lipman, Dean and Director of the New Jersey State College and Stations, accompanied by Mrs. Lipman, sailed April 9th on the America for France, from whence he will proceed by way of Switzerland to Rome to attend the general assembly of the International Institute of Agriculture, as official delegate of the United States Department of Agriculture. Immediately following this meeting, he will attend the Fourth International Conference of Soil Scientists for which he has organized the program of Soil Bio-Chemistry and Micro-Biology for North and South America and Asia. He will represent, among other organizations, the American Society of Agronomy and the National Research Council.

G. H. Stringfield, formerly of the Nebraska Station, is now Assistant Agronomist of the Ohio Agricultural Experiment Station, at Wooster, Ohio.

Dr. S. A. Waksman, of the New Jersey Experiment Station, sailed April 9th to attend the Fourth International Conference of Soil Scientists at Rome.

George A. Jackson, Assistant Extension Agronomist of the Virginia Agricultural Experiment Station, was in Delaware on April 11 and 12, to consult with the soybean growers of that state about the organization of a crop improvement association and central marketing agency.

Dr. H. V. Harlan, Agronomist in charge of barley investigations in the Bureau of Plant Industry of the United States Department of Agriculture, returned to Washington recently after a year's trip through Spain, North Africa and parts of India in search of cereals which might be used in attempts to improve varieties now grown in this country. He brought back with him stocks of seed of barleys from the northern plateau of Spain; several barleys which are indigenous to the oases of the Sahara desert; barleys and other cereals from the Vale of Kashmir and from the plains of the Punjab in India; and many types of barley, wheat, emmer, teff and grain sorghums from Ethiopia in Africa.

INCREASE IN CROP ACREAGE IN THE UNITED STATES

According to the report of the Crop Reporting Board of the U. S. Department of Agriculture, farmers of the United States planted 341,000,000 acres of the fourteen principal farm crops in 1923. This was an increase of more than 2,000,000 acres over the plantings of 1922. The production of the fourteen crops was estimated to aggregate 265,000,000 tons, or about the same as in 1922 and 11,000,000 tons larger than the ten-year average.

WESTERN CANADIAN SOCIETY OF AGRONOMY

The published Proceedings of the third annual meeting of the Western Canadian Society of Agronomy, which was held in Saskatoon, Alberta, on December 27–29, 1922, are now available for distribution from the offices of the Saskatchewan Department of Agriculture, Regina, Saskatchewan, Canada.

The program of the meeting was as follows:

President's Address—Progress in Agronomy in Western Canada, G. H. CUTLER.

Agronomy as a Subject of Instruction, L. E. KIRK.

Hardiness Studies with Winter Wheat, R. NEWTON.

The District Representative as a Link in Extension Service, N. C. MACKAY.

Soluble Nitrogen as the Limiting Factor in Northern Crop Production, W. D. ALBRIGHT.

Thirty Years of Cereal Investigations in North Dakota, H. L. WALSTER.

Agronomic Conditions in Manitoba as Revealed by the Agricultural Survey of 1921, J. H. ELLIS.

Lethal Factors in Cereals, W. P. THOMPSON.

Potato Diseases, G. R. BISBY.

The Milling Value of Saskatchewan Wheats, C. H. GOULDEN.

Water Requirements of Crops, W. H. SNELSON.

Methods of Keeping Records of Cereal Breeding Investigations, J. B. HARRINGTON.

Experimental Methods with Special Reference to Uniformity of Descriptive Terms, G. P. MACROSTIE.

Soil Moisture Studies at the Dominion Experimental Farm, Swift Current, Saskatchewan, S. BARNES.

Reports of Committees:

- Instruction,
- Plant Breeding,
- Soil Management,
- Crop and Seed Technology,
- Extension,
- Summerfallow Substitutes,
- Pathology.

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1. THE FUTURE OF THE SOIL SURVEY IN OUR NATIONAL AGRICULTURAL POLICY[1]

MILTON WHITNEY[2]

The ancients, so far as the history and traditions which are available to us show, were curious as to what made plants grow and as to why crops grew differently in different localities and on different soil types. In the earliest stages of the life of human beings on the earth, when men depended upon the wild things of nature, they were keen for a knowledge of where their necessities could be obtained. In the early nomadic life of the people, it was essential for them to know where the best natural food for their flocks and herds could be obtained. Such people needed only general information.

As the nomadic life gave place to the sedentary life and the growing of crops, men needed more particular information, since to produce crops they had to settle on a definite piece of land. The selection of the land where they should settle became of supreme importance. When a country was sparsely settled, knowledge of the soil type was relatively unimportant because of the abundance of land available and the people were able to support themselves in a way on the product of their labors. As the country became more densely settled, more and more organization had to be introduced, with a consequent increase in taxes and in public improvements, and competition became greater and more intensive effort became necessary.

According to the early Chinese records, which are apparently authentic, in the Yao dynasty from 2357 to 2261 B. C. certain parts of that country were then so thickly settled that the emperor directed

[1]Paper read as a part of the symposium on "The Utilization of the Soil Survey" at the meeting of the Society held in Chicago, Ill., November 13, 1923.

[2]Chief, Bureau of Soils, United States Department of Agriculture, Washington, D. C.

that there be made what was probably the first soil survey and there were established nine different types of soil.[3] There were the yellow and mellow soils of Yung Chow (Shensi and Kansu), which were put into the first class; and the red, clayey and rich soils of Su Chow (Shantung, Kiangsu and Anhwei), which were put into the second class. The third class comprised the whitish and rich salty soils of Tsing Chow (Shantung); while in the fourth class were placed the mellow, rich, dark and thin soils of Yu Chow (Honan). In the fifth class were the whitish and mellow soils of Ki Chow (Chili and Shanse); in the sixth class the blackish and rich soils of Yen Chow (Chili and Shantung); and in the seventh class the greenish and light soils of Liang Chow (Szechuen and Shensi). The miry soils of King Chow (Huen and Hupeh) were in the eighth class; and the miry soils of Yang Chow (Kiangsu) were in the ninth class. On this classification was established the size of the holdings of each farmer, the amount of the taxes payable to the state and the system of education regarding agricultural methods and procedure.

The early Greek and Roman philosophers whose writings have come down to us show a very intimate knowledge of the relation of soil types to crops, especially the writings of Cato, Columella and Pliny. They dwell upon the importance of selecting the right kind of soil for a definite crop or system of crop rotations and warn against the use of soil types for crops and industries to which they are not adapted. They ascribe many of the failures of agriculture in their times to a lack of appreciation of the adaptation of crops to soils.

The history of agriculture in the north of Europe, from the latter part of medieval times to the present, shows a gradual application of the adaptation of crops to types of soils as exemplified in the agricultural policy of Germany up to the time of the recent war. Practically, that nation had been working out, for a thousand years, an agricultural policy which recognized as separate units the moor soils, the sandy soils, the clayey soils, the soils adapted to sugar beets, to potatoes, to the dairy industry, to grain farming, to wine production, and a multitude of other crops and of other industries.

The great economic crisis in England at the close of the baronial period, when the open field system was displaced by the inclosure system, made possible individual competition and the adoption of the principle of the adaptation of soils to crops and all that has since developed in the perfection of methods through individual effort.

It must be remembered that the art of surveying and map con-

[3]See Miss Mabel Ping-Hua Lee, An Economic History of China with Special Reference to Agriculture. Longmans, Green and Co., New York, 1921.

struction has been developed in any adequate way only within recent years and that statistical work as applied to crop production is a matter of recent times. With the perfection of maps, the development of statistical science, and the accumulation of the knowledge of the constitution and properties of soils to serve as a guide, it remained for scientists in the early part of the twentieth century to begin the actual differentiation or classification of soils portrayed on maps and to record those fundamental facts which have always been, in theory at least, the fundamental basis for an agricultural program for a farm, a country, a state, or a nation. The soil map is a visualization of the aspirations and desires of mankind throughout the ages. The soil survey therefore is putting such data, under scientific methods of classification, on maps for the benefit of the present and of future generations upon which to build a national agricultural program.

Other speakers at this meeting will tell of the present use to which the soil maps are put—the information which they give to the present owners of the land in regard to soil conditions on their own and on their neighbors' farms so that they may correlate their own successes and failures with the experiences of others who occupy the same types of soil. They will tell of the use of the soil map to the prospective settler who elects to move from one part of the country to another, of the use of these maps by the experiment stations and by all workers in agricultural lines of research, and of the use of these maps by bankers and investment companies and by real estate agents. They will tell of the stabilization of land prices, and of systems of taxation.

I have elected to give this brief historical review because I think it cannot help but impress you and impress others with the same feelings which I sincerely hold; that, as time goes on, as our population increases, as the struggle for existence in this and in other countries may become more acute, the soil survey will be more and more appreciated and more and more essential to the organization and upbuilding of the highest possible development of agriculture.

What the Japanese have done, in their six thousand years of historical occupation, in the adaptation of their soils to crops throughout their provinces; in the knowledge and experience that has been handed down from father to son; in the regulation and control of their lands; what the Germans have done in the past thousand years through experience and through force of necessity, in the regulation of their crop adaptations to soil types; the scientists of the twentieth century should do more intelligently and more quickly, with the knowledge afforded by the soil survey and the studies that are being made of our soil types.

The English have increased their yield of wheat during the past three hundred years at the rate of about eight bushels per acre per one hundred years. During the past forty years the United States has increased its yield of wheat at a rate of about twelve bushels per acre per one hundred years; but even at this rate we are about one hundred years behind the present development of yields per acre in England.

With the knowledge presented by our soil surveys and the proper utilization of our soil types in their adaptation and treatment we should be able, through force of intellect and knowledge, to establish and maintain a more rapid increment than has been accomplished in the north of Europe by necessity and through the acquisition of knowledge of their soils through innumerable failures and a few accidental successes.

The agricultural industry in the United States is now and has been for many years rapidly changing. It is not stable, but is developing rapidly and in the course of the next fifty years will probably be entirely reorganized. In this reorganization the soil survey will unquestionably play an exceedingly important part. With 87½ per cent of the acreage in crops at the present time devoted to five crops, cotton, corn, wheat, oats and hay, and with the more or less complete segregation of the commercial production of these staples to different sections of the country we do not have and cannot have a national rotation policy such as is one of the recognized essentials in the increasing of productivity. In this respect we are not far removed from the medieval system prevailing in Europe when the open field system was in use. A full knowledge of the adaptations of our soils should make possible a type or types of agriculture in which rational crop rotation can be maintained.

2. DIFFICULTIES IN UTILIZING THE WORK OF THE SOIL SURVEY[1]

A. R. WHITSON[2]

The utilization of the work of the soil survey depends on at least three factors: first, the usefulness of the information collected; second, the manner in which this information is expressed in the report; and third, the extent of distribution of the report.

INFORMATION GATHERED BY THE SOIL SURVEY

The information gathered in the progress of the soil survey may be classified into two types; first, that which may be used by persons or organizations interested in a variety of phases in agricultural and rural conditions, including research departments of the experiment stations, banking, and other loan organizations; highway commissioners and others concerned in the construction of roads; people looking for land as prospective settlers, and those engaged in assisting them in that purpose; those seeking to locate enterprises connected with agricultural development such as canning factories, provision warehouses, etc.; and those having an interest in the educational and social development of rural life. The second type is that which may be used by the farmers, or actual occupants of the land itself.

In order to collect the information along the various lines which are of interest to these different users, the soil surveyor must keep the different classes of people distinctly in mind and, as far as possible, see that his map and accompanying notes and records are made in such a way as to supply the information which is needed.

While the older maps and reports were undoubtedly of great value, they left much to be desired and are considered incomplete and unsatisfactory by many people who are now undertaking to secure the information they need from them. A general criticism may be made of these older maps and reports that they were based too largely on the geological nature of the basis of soil classification and mapping. Such classifications in mapping of the soil have considerable value and are particularly useful as a basis for further investigations of soil problems, especially those of chemical and physical nature; but they neglected many very important and practical lines of information which people of the several classes mentioned above are constantly

[1]Paper read as a part of the symposium on "The Utilization of the Soil Survey" at the meeting of the Society held in Chicago, Ill., November 13, 1923.

[2]Chairman of the Department of Soils, University of Wisconsin, Madison, Wisc.

seeking and can secure only through detailed soil survey reports and maps.

From a careful reading of many of the older reports, it appears to the writer that much improvement can be made if those in charge of soil survey work will secure the cooperation and suggestions of the various specialists who need information which can be secured by the soil survey. Among those whose advice should be secured are agronomists, working with a variety of crops; road commissioners, whose work involves the use of material for road construction; bankers, and those in charge of financial organizations generally who are engaged in the placing of farm loans; tax commissioners, who can use the maps of the soil survey when properly made; and officers of canning companies and other similar enterprises. Through conferences with these different people and probably in many cases by having them occasionally accompany the soil survey parties in the field very much more definite and specific information of value can be secured.

One difficulty in the securing of the miscellaneous information above suggested, which is usually encountered in the routine work of the soil survey, is that the interruption caused when any individual member of the party delays the progress of his mapping for such purposes interferes with the work of other members. It would be practicable, however, for the leader of the party, whenever desirable, to devote certain days entirely to the gathering of this additional information; since he would then not interfere with the systematic mapping being carried on by the remaining members of the party. To do this work successfully, a leader should, of course, be thoroughly trained in practical agriculture and well acquainted with the various uses to which the information will be put. This requires a man of exceptional qualifications and one the value of whose services is fully recognized in the salary which he receives.

In the soil classification itself considerable improvement can frequently be secured by the use of phasal distinctions to indicate variations in main types which are of practical importance. Among these may be mentioned the phases of types which need drainage, others which are subject to erosion, those which are particularly stony, etc. It is these practical phasal distinctions in which the farmer, as well as the business man, is chiefly interested.

While the soil maps and reports should include much information of interest and value to the public as above suggested, they are of course primarily intended for the use of farmers. This should be kept distinctly in mind in preparing both the map and report. The

farmer's attention should be directed to improvements which a thoroughly trained surveyor can suggest by indicating the need of drainage, of methods calculated to prevent erosion, of land needing the use of lime, increase in organic matter, or improvement in other lines. As far as possible, these conditions should be expressed on the map itself, as well as discussed in the report, since the farmer may not examine the mapping of his own land when he has a map and report in hand, even though he cannot get the information the report is intended to convey if he fails to read it fully. But if these conditions can be expressed on the map his interest is aroused and he is more likely to look for further information in the body of the report.

The manner in which the report presents the information which has been collected during the survey has much to do with the extent to which it is read and used. Specialists in any department of agricultural science must constantly bear in mind the complexity of the subject of agriculture and the fact that their own field is but one of a large number in which their readers are interested. The information they have to convey should be expressed as clearly and definitely as possible and all unnecessary or irrevalent matter should be omitted, since this simply serves to lessen the readiness with which the desired matter is reached in the report.

It has been pointed out that there are two general classes of persons who use soil survey reports. First, the general or public class; and second, the individual farmers. It seems to the writer that much could be gained if two types of reports were published, and since most states are now cooperating with the Bureau of Soils in the soil survey work it would appear practicable that the Bureau's edition of the report might be written primarily to furnish the general information above suggested, while the State's edition of the report could be written with the point of view of the individual farmer chiefly in mind. There would of course, be some objections to this plan and some difficulties to overcome, but certainly much would be gained in that each report could be written with its readers more distinctly in mind than would otherwise be possible.

Even after every effort has been made to improve the character of the information gathered and the form in which it is expressed in the report, little will be accomplished unless these reports finally reach the hands of those for whom they were written. This requires constant advertising of the work of the Soil Survey. It is probably true that the general class of readers who are more accustomed to seek information through books and reports learn of them and can use them

more readily than can the individual farmer. A small percentage of farmers are constantly in touch with the State experiment stations and secure their reports and bulletins, but many who could profit by the work of the Soil Survey never see its reports. It should be considered a regular part of the duties of the men in the field to secure the names and addresses of farmers in the territory in which they are working and to prepare a mailing list, especially of all those on farms for which important suggestions for improvement are embodied in the report. It is possible that this work could be largely done by the leader of the field party during the time he is not actually engaged in mapping, as has been suggested. If when the report is sent it could be accompanied by a brief personal letter to the farmer, this would aid greatly in attracting his attention.

3. THE RELATION OF THE SOIL SURVEY TO THE SETTLEMENT OF UNUSED LANDS[1]

Thos. D. Rice[2]

The problems arising in the settlement of the unused lands may not seem of any great importance at the present time, when improved farms are being abandoned and when there is little movement anywhere towards lands of doubtful value. Economists, however, agree that the agricultural depression now prevailing is only temporary. One need not possess prophetic vision to predict that, within a very few years, the tide of population now flowing towards the cities will turn and there will be another rush of settlers to the marginal lands. The settlers of this next invasion will probably stand in more need of assistance in selecting land and be more willing to receive such assistance than those of any which has preceded, for it will be composed not so largely of experienced farmers moving a short distance on to good land but of men of all sorts, many of them from the cities, who seek to take up land in sections where they know little of the soils and agricultural conditions. It is reasonable to suppose, therefore, that a greater number of these will require assistance in selecting their land and that the soil survey and other branches of the agricultural departments will be called on for advice.

The soil surveys, state and national, have accumulated a vast amount of information concerning a large part of the unused land,

[1]Paper read as a part of the symposium on "The Utilization of the Soil Survey" at the meeting of the Society held in Chicago, Ill., November 13, 1923.

[2]Inspector (Northern Division), Soil Survey Investigations, Bureau of Soils, United States Department of Agriculture, Washington, D. C.

which should be of value to the prospective settler if properly presented. That such information has been of value in the past can be proved by a great number of known cases. Whatever doubt may be held as to the ability of the resident farmers to make direct use of the soil survey map and report, there can be no question that prospective settlers have in a great number of cases made immediate, practical use of this information. Many settlers have been prevented from taking up worthless land, others have been guided in selecting the best type of soil in a given tract, and farmers and fruit growers, by means of the soil survey, have found the soil and the location suited to their needs. With increasing knowledge of soils, even more help of this kind should be furnished in the future. In many cases, the soil map and report can supply the prospective settler with the information that he needs; in other cases, these publications must be interpreted and made more available for his use; and often they must be supplemented by the reports of the agronomist and the economist. In all cases, however, the soil survey report is the foundation upon which any valuation should be built.

The criticism is sometimes made that the soil survey report does not place sufficient emphasis on the deficiencies of soils of low value that are sold to the unsuspecting public. While this may seem to be true in some cases, it is not because of any lack of courage on the part of those in charge of soil surveys. The use of the soil survey to help and protect the prospective settler is not so simple a task as those who have never studied the subject might suppose. Several years ago a writer for a well-known periodical prepared a series of articles on the shortcomings of the United States Department of Agriculture. In discussing the Bureau of Soils, he contented himself with a denunciation of the Soil Survey for not publishing facts concerning land values in all parts of the country in order to prevent fraud. This writer seemed to think that it would be easy to give each acre of land in the United States its value in dollars and cents. He had apparently given little thought to the magnitude of such an appraisal. He had also not informed himself of the great amount of advice which is given to settlers by the Bureau of Soils and the officials of the various state surveys, nor had he taken into consideration the difficulties that confront us when we attempt to extend this service.

In the past one difficulty has been the lack of information concerning a large part of the unused land. Little knowledge of the soils in these lands is available, because requests for soil surveys have come mainly from the older, well-settled communities. Where soil surveys

have been made, the Bureau of Soils has been handicapped by not being able to make experiments to determine the value of the different soil types. It is unjust to condemn a section, or a soil type, unless it is certain that all the facts in regard to the soil and the agricultural conditions that now prevail are known and that the future possibilities are taken into consideration. It is fully as great a wrong to destroy the equity of one man in his land by an unjust or hasty report as it is to fail to prevent the swindling of another who would be deceived into buying such land. As in the administration of justice, it is difficult to be efficient and at the same time absolutely just in every instance. In spite of the effort to be fair and conservative, the soil survey reports in some cases have worked injury and perhaps injustice to individuals. A fair appraisal of land values involves not only a consideration of all the facts that are available in regard to the soil itself and the agricultural conditions that now prevail, but also of the future possibilities. Irrigation, drainage, a change of market conditions, or the introduction of a new crop, may give a high value to a soil formerly considered worthless. One need only cite as illustrations of such transformations, the irrigated districts of the west, the deep sands of Florida which have become valuable truck and citrus soils, or certain muck soils where celery and other special crops are now grown. It will be seen that to be fair to the land by taking into consideration all its present advantages and making due allowance for future changes and at the same time not give aid and comfort to the real estate swindler is a task calling for much discretion—to say nothing of a gift of prophecy.

Even where it is certain that a tract of land is being misrepresented and loss to the settler could be prevented, there is local opposition to be met. In the past, the opposition of the real estate dealer did not present the most formidable difficulty, since his criticism of the soil survey report was to a large extent discounted by the public. The local pride and mistaken self-interest of the community were most difficult to combat. All civic organizations and the public press were turned against what was represented as a disparagement of their community. In some cases, local and state officials have considered it their duty to defend a soil type and encourage an influx of settlers regardless of the facts. Happily, this kind of opposition has almost disappeared. Most states and communities now take the broad view that no lasting benefit can result in having settlers come in and lose money. States which have vacant public lands are now earnestly seeking facts concerning the soils on these lands and seem determined

that the robbery of ignorant settlers by the state itself shall not be repeated.

Another kind of opposition which has been met in the attempt of governmental agencies to help and protect the settler arises from the old prejudice against state intervention between buyer and seller. Even where the principle of such intervention is accepted, it is a problem as to how far the state can go. A settler may be ruined as certainly by paying too high a price for good land as by paying a low price for inferior land, but it is not possible to intervene and tell him that a particular tract of land is worth $100 but not $150 an acre. Nor can the law give him any adequate protection. The United States courts cannot undo a wrong of this kind, but can only protect other possible victims by convicting the swindler for placing in the mails statements that he knows to be false. It will be seen that many kinds of frauds cannot be prevented nor their perpetrators punished under the Federal law. It is not so often questioned, now as formerly, whether the state has the right to protect fools, where such a thing is possible, but the old doctrine of *caveat emptor* can never be entirely dispensed with. The settler, unless he can employ an expert appraiser, must rely to a considerable degree on his own judgment in regard to land, even in those states where every legal safeguard has been thrown around him. The national and most state governments must confine their service to supplying him with information by which he can interpret the results of his own observation. The soil survey cannot over-advertise its service and further spread the impression that definite advice whether or not to buy a particular tract of land at a given price can be given the settler. There should, however, be placed before the public exact information of what the soil surveys and other branches of agricultural research have to offer. At the present time, the prospective settler, in most cases, even if he is intelligent and fairly well informed does not know that valuable information can be had for the asking. Some such persons call on the soil surveys for information, but the number of these is small compared to those who go without any guidance to take up land in regions where they know little of the soil and local conditions. These individuals ought not to be criticized, however, in view of the fact that officials of other departments of the state and national governments and even workers in our own departments of agriculture are ignorant of the work done by the soil surveys and of the store of information that is available.

In the future, it will be the task of the soil surveyor and the agron-

omist to overcome these difficulties and to be ready to assist the new settler in every possible way. The following are several lines of service which are now open:

It is the duty of the soil surveyors to continue soil research by gathering information and by mapping soils in as great detail as possible. A soil map on the usual scale may not seem adequate in many cases; the soils may be so complicated or subject to such local variations that it is difficult for the land seeker to get definite information on any small area. In such cases, he must be taught to recognize these soil variations and instructed as to what to avoid. Cooperation with the agronomist in follow-up work is necessary in order to determine the value of many soil types. Before this information goes to the settler, those factors which are not directly related to the soil but which greatly affect land values, such as markets, roads and social conditions, should be checked over by experts on these subjects. It is also of the greatest importance that this information should be combined and expressed in non-technical form, so that it may be understood and used by the average man.

The second task before the soil surveyor and the agronomist is to determine how best to distribute this information, so that it may be available for the settler and for those who are advising and financing the settler. Beginning at home, the workers of the United States Department of Agriculture and of the different state departments, who may be called upon for advice for settlers, should be instructed how to interpret and to use the soil survey reports and the results of the follow-up work of the experiment stations. A special effort should be made to reach the county agents and the extension workers who come in direct contact with the farmers.

It is not so easy to reach the great number of people who may at any time become land seekers. Where the state has an efficient immigration department or a well-administered "blue-sky" law, it becomes much easier to help and protect the settler, as his welfare is then in the hands of officials who specialize in this service. Unfortunately, in some states these officials have not been informed of the facts that are available for their use nor have they been instructed how to interpret a soil map and report.

Much good can be accomplished by distributing information and by demonstrating the value of the soil survey to the land appraisers for loan companies and banks, for the institutions which they represent can exert a great influence against unwise settlement.

An effort should be made to reserve more of the soil survey reports

for the use of prospective settlers and to prevent their random distributions to persons who have no particular interest in the subjects treated.

A third duty of the soil survey in protecting settlers, and a most unpleasant one, is to assist the federal and state authorities in collecting evidence, which may be used to prosecute swindlers in the land business.

These are some of the opportunities for service that lie before the soil surveyor and the agronomist in connection with the settlement of the unused lands, and some of the difficulties which they may expect to encounter. It is hard to overstate the importance of this service when it is considered in relation to the waste of human lives. The history of the haphazard undirected settlements in the past is familiar to all. While the rich prairie lands were being taken up, no one could go wrong. The settlement of the cut-over lands, the swamp lands and the arid lands, however, has had a history both of many successes and many failures and these failures make up an appalling total in wasted money and wasted lives. Much of this loss could have been prevented. Those of us who have worked on the soil survey have seen the hard struggles of many a pioneer, who has wasted the best years of his life on a worthless soil, while quite near by was valuable land that he might as well have taken. That phrase "the years that the locust have eaten" is quite expressive of the ravages of age, but it carries no more tragedy in its meaning than the years that have been eaten by worthless soil, by drought, by flooding and by alkali. Must this history be repeated when settlers again attempt to take up the unused lands? Is it not the duty of the soil surveyor and the agronomist to prevent as far as lies in their power such a repetition of wasted effort?

4. THE RELATION OF THE SOIL SURVEY TO THE UTILIZATION OF SOUTHERN SOILS[1]

Hugh H. Bennett[2]

Dr. Call's letter of July 24 concerning the preparation of a paper on the relation of the soil survey to the utilization of southern soils, for the joint meeting of the Society of Agronomy and Association of Soil Survey Workers, reached me in the latter part of August at San

[1]Paper read as a part of the symposium on "The Utilization of the Soil Survey" at the meeting of the Society held in Chicago, Ill., November 13, 1923.

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Jose, Costa Rica, just as we were starting on a long trip by trail and boat through Costa Rica, Nicaragua, and Panama. This night of October 22 is the first opportunity there has been even to reply to Dr. Call's letter; and, since we sail day-after-tomorrow for a ten days trip up the Chucunaque River (provided we can get by the dead-line of the Chucunaque Indians) there are left but a few hours to devote to this paper, which is being begun with the thought that it will probably be too late for use at the Chicago meeting, even should anything of value slip into the product of the night's effort. Time and thought should be devoted to a paper of this nature: neither seems to be available at the moment. Too much rain; too much mud; too much rough trail; strange soils, clays without a recognizable grain of sand, yet as friable as a loam; vast plantations of bananas where the fruit is planted in the tropical jungle and the jungle felled upon it and left to rot, the ground never being stirred; all these create a confusion, from which surely not much will be demanded.

Soil surveys have shown that the southern states embrace soil differences of such multiplicity; of such varied characteristics; of such divergent productive values, manurial requirements and crop adaptations; that nothing short of a ponderous monograph would give even an approximation of a comprehensive discussion of the actual variations and conditions. Nothing of the kind will be undertaken.

The results of the surveys are on record in published reports, free to all, open to the inspection of all. Hence, it should not be necessary to spend time in explaining the nature of the work or apologizing for any shortcomings that the skeptical critic may point out.

There are critics, of course; like the poor, they will always be with us—indeed, they have undoubtedly a proper place in human affairs. Once started along the right lines, however, it is not inconceivable that highly valuable results will accrue from the efforts of the most touchy and critical experimenters. There is a saying in the British army to the effect that the private of the chronic-grouch type (he who says over and over to his soldier-mates, that the officers are inefficient, the quarters rotten, the beans always too salty, the guns no good, that everything is wrong and the army is going to pot) makes the best fighter when things begin to hum, and when he gets to going.

So, to those who object to the lack of detail on ancient soil maps or the great detail on the more recent maps let's say: "Well, but we are not going to get anywhere unless you start right now and find out something about the specific needs of specific soils, such as, whether it

is nitrogen which the Sharkey clay of the Mississippi Delta needs and potash which the Sarpy fine sandy loam of the same region needs for the production of best crops of cotton."

The state of North Carolina entered into cooperation in soil survey work about 1901. The workers in that state have stood by this work actively until the present and show no signs of quitting. Long ago the central station at Raleigh established sub-stations on the important soils of the state, those which had been proved to be important by soil surveys. On the granitic soils, the Cecil types, by experimentation potash was found not to be of particular value for cotton or corn; whereas on the sandy Norfolk types in the eastern part of the state, potash was found to be of considerable value. Workers in North Carolina have experimented by soil types and farmers have profited by the results of experiments that are applicable to the soils of their own farms as distinguished from the soils of other farms in other parts of the state, which are of entirely different character and have entirely different requirements.

In Extension Circular No. 32 of the North Carolina Experiment Station the statement is made that "In this state all experimental work with fertilizers on soils and of variety tests of crops is carried on with reference to soil types. At first, the larger and more important types were selected for location of the test farms and the outlying fields. Later on, it is planned, as rapidly as funds are available.... to extend the investigations to the agricultural types of the State that occur in less extended areas. It can readily be seen in such a plan that after definite information has been secured from the field, the results may generally be applied to most all the farms located on the same type of soil...."

North Carolina is by no means the largest state in the Union, nor of the southern states. Nearly one-third of its area is comprised in the Blue Ridge Mountain region, where a large proportion of land is too steep for tillage; there are no limestone soils in the state, nor any vast areas of rich, alluvium or delta land or black prairie or mellow, loessial silt loam. There are sandy soils in its Coastal Plain, and other kinds too; red clay loams and other types in the Piedmont; and a variety of residual soils derived from crystalline rocks in its western mountainous section. Now, if these soils are not farmed efficiently, how is it that in recent years the value of the crops of this state has been exceeded only by the values of the crops in Texas, Illinois, Iowa, and sometimes by those of California, and not by those of any other state of the United States? The acreage valuation has made an even

better showing than this, exceeding in some years that of the four big states named and nearly all others, with the exception of some small New England states, where relatively small areas are devoted to highly specialized types of farming. Check these statements by the figures of the crop statisticians, please.

This sounds like a boost for North Carolina. It is. But is it not a sort of boost, too, for soil survey work, inasmuch as that state took up soil survey work before any other state did and never quit? (Yes, the writer of this paper is a North Carolinian—does some farming there, and thinks he knows something about the soils down that way, technically and otherwise.)

Workers in Texas are also using this soil type plan for locating substations; in fact, they have been developing along that line considerably in recent years. This year the director of the experiment station took soil survey men along with him to identify the soil types down in the Rio Grande Valley, where he was examining certain sites which were under consideration for the location of the South Texas experiment station. It is well to study the soil types of any region, whether the location is being sought for an experimental farm or a farm for more selfish consideration. Even the Rio Grande Valley has spots of alkali soil that do not lend themselves readily to ordinary methods of farming. They sometimes have to be handled according to their own peculiar requirements in order to be induced to produce bountifully; if they are not handled just this way, some of them, they are liable to produce disappointing results. Farmers have fallen upon sad times in not a few instances where they have undertaken to operate against the precise and insistent demands of obstinate soils. This happens in pretty nearly all regions.

It has frequently happened that men have undertaken the cultivation of timber lands for farm crops. Land sharks lay their hands upon a considerable number of novices and even of practical farmers; considerable numbers of farmers fool themselves, simply because they do not understand the soils of new regions into which they have migrated; while some fail on the lands at home for the same reason. Soil survey reports include much valuable information that should be more generally used from the standpoint of selecting farm lands, especially in new localities. There is an almost incalculable amount of immediately valuable data in the average soil survey report. There are sections where a soil map would be of almost inestimable value to a newcomer seeking farm land, even if it did no more than to show that the southern half of a county was occupied mainly by the Susque-

hana clay and the northern half by the Orangeburg sandy loam. Anyone who can read can understand some such simple statements as the following: "The Susquehana clay is a red, heavy clay underlain at 3 or 4 inches by an extremely plastic, impervious heavy clay, containing very little sand. It is a type of soil which is difficult to till, which erodes severely on cultivated slopes and produces low yields. It is best suited for the growing of pine trees for timber. The Orangeburg sandy loam is a brown, friable sandy loam underlain at depths of 8 to 10 inches by a red, friable, sandy clay. It is easily cultivated, has a wide range of crop adaptations, and with fairly liberal fertilization produces good yields of corn, cotton, and tobacco."

Just such statements are to be found in many of the soil survey reports. Often these are elaborated, it is true; but the statements are there, usually presented in plain English, and they are facts, valuable facts, which somehow should be given more publicity.

The soil survey reports contain information that should help toward achieving a better use of our soils. Not all of the soils of the southern States make good farming lands; many steep-sloped areas are much better suited to forestry than to cultivated crops; certain inferior soil types, as the Susquehana clay, are better pine soils than farm crop soils; and these are the uses to which land of this kind should be put. The timber is needed, and will be more and more acutely needed in the future. It should not be overlooked that the pine tree grown on pine-tree soil is a profitable crop, not for western Texas or western Oklahoma, but for a large part of the Southeast.

The following re-statement of some estimates recently made which relate to forestry lands and a more profitable use of forestry lands in the Southeast will be of interest in this connection. These estimates cover a large area in the southeastern states, including the Ozarks, southern Appalachians, southeastern Coastal Plain, Mississippi lowlands, and the southern loessal region. Four major classes of soils were employed in this appraisal, these being based upon the value of the land for farm crops, forestry, and grazing. The estimates for the extent of land falling into these several groupings were based upon actual soil surveys of over 95,000,000 of the 293,000,000 acres embraced within the area studied. Approximately 176,000,000 acres or 60 percent of the region fell into the group of *farm land*; 54,000,000 acres or 18 percent was classed as *forest and grazing land*; 54,000,000 as *reclaimable wet land*; and 10,000,000 acres as *marginal land or land of doubtful farm value*. The proportion of improved farm land for these classes, using the estimates of the last census as a basis and

distributing the areas among the soil types according to their applicability as determined by field studies, is as follows: farm land, 48 percent; forest and grazing land, 7 percent; reclaimable wet land, 3 percent; and marginal land, 12 percent. Thus, more than half of the farm lands for the area under consideration (about 91,000,000 acres) represents unimproved land, according to these estimates. This consists of idle cut-over land, land in timber, and old fields lying fallow. Most of it lies in the cut-over pine-belt. The better farm lands are comparatively smooth in topography and well drained. They range from deep fine sands and loamy sands through sandy loams and gravelly loams to the heavier grades of soil—the clay loams, clays, silt loams, and loams. In productivity, they range from moderately good to very good.

What is to be done with the large excess of unused arable land? It may be assumed that no one will question the advisability of using it for crop production before attempting to use the poorer grades of marginal and forestry lands. But there is little probability that all of this vast area will be brought into cultivation in the near future. Indeed, its immediate utilization for crop production undoubtedly would be unwise, because an over-production of some crops would be the probable result. These lands should be, and undoubtedly will be, taken up gradually, furnishing acreage for large extensions in the production of corn, potatoes, sugar cane, cotton, rice, peanuts, tobacco, forage, hay, feed stuffs, and other crops to which they are suited. The better and more accessible areas should be improved first. While this is being done, it would seem advisable to make some use of the less accessible areas. The most promising use for them appears to be for forestry and grazing.

There is room for extensive utilization of both fair and good idle farm land for timber production, without any cramping of agricultural development in this region. Nevertheless, the aim should be, to bring about first the early inclusion of as high a proportion as practicable of the true forest land in the larger forestry projects. It is desirable that utilization for timber production of the forest land, the inferior farm land, and the relatively inaccessible better grades of soil, should proceed with a sufficient regard for proportion or balance to invite public cooperation by its economic soundness.

Agricultural conditions over much of the territory can be improved greatly by betterment of the animal husbandry industry, both through increased numbers of animals and improvement of breeds. Already, much has been accomplished in this direction, notably in the southern

Coastal Plain, where the raising of cattle and hogs has been so much increased in recent years that packing houses have been built in many localities. The velvet bean, peanut, sweet potato, and lespedeza have been indispensable instruments in achieving this advancement. Within fifteen years, the velvet bean has grown from a crop of insignificant importance to a point where most of the corn in the lower Coastal Plain region east of the Mississippi is grown in combination with this crop. It is the most important forage crop of the southeastern Coastal Plain, and with the breeding of earlier varieties, its production is gradually extending northward. In addition to being one of the best forage crops known, it is a splendid soil builder. The use of the peanut and lespedeza, also, is spreading rapidly.

In some localities, where the boll weevil has made appalling inroads upon the cotton crop, velvet beans, peanuts, sweet potatoes, lespedeza, cattle, and hogs have saved the situation for the farmer. In certain localities in southern Alabama, the change in methods of farming which was enforced by the weevil invasion has had a profound effect upon the economic situation. Formerly, in these localities, farmers bought their supplies on credit at high prices from merchants who took a lien upon the farmer's property, or his prospective crops, or anything that was his, or that was likely to be his. In some of these localities, this system of credit has now been largely displaced, and the banks have double the deposits they had before the weevil came. Fields have been fenced; highways have been improved; and, in every sense, the farmer is better off. Some cotton is still grown, but it is grown under intensive methods and not as the sole money crop, as it was under pre-boll-weevil conditions.

These communities have shown that tremendous advances can be made in the improvement of the agriculture of the Coastal Plain region. Broadly speaking, the same methods are applicable to much of the Piedmont country and to other parts of the Southeast. Correct usage of land and diversified farming, including production of a large proportion of farm supplies on the farm and the raising of stock, are the means that will bring this part of the country gradually but surely to a higher state of agricultural development. With the large number of crops suitable for field forage, hay, and concentrated feeds for live stock and dairying, which succeed so well under the varying conditions of soils, climate, and topography; with the broad range in soil adaptation from general farm crops to highly specialized crops; and with the poorer grades of land largely well suited to timber and grazing; there is no real need for dwellers in this region to become

pessimistic over such a misfortune as the boll weevil depredation or over such things as increasing foreign competition in the production of cotton. The farmers in this section have but to utilize their soils more nearly in accordance with their natural adaptations, to diversify their crops rationally, and to save their lands from erosion. They are advancing in the matter of correct soil usage. More terracing is being done in the Piedmont region and parts of the Coastal Plain to protect the slopes from erosion than anywhere else in the country. Agricultural practice generally is improving in numerous locations.

Let's get the notion, even make an obsession of it, that better soil usage—usage more nearly in accordance with the requirements of the soil type—is necessary to our present welfare and to that of our children's children. Let's take better care of those types of soil which are peculiarly susceptible to ruinous erosion and use them for timber and grazing where necessary. Let's keep a proper balance, however, and not be stampeded into too narrow channels of thought and endeavor. There is no intention to urge the narrow and unwise idea that every acre of land can be used in exact accordance with its precise adaptations and requirements. Due regard must be had for the economic use of farm labor and machinery throughout the year; for soil-building rotations; and for market gardening near urban centers where soil type often can be disregarded to some extent. It is the larger problem that concerns us, namely, the wise use of areas of land largely in excess of the necessary exceptions to the general scheme of utilization proposed, where we should strive for better use of the land. More experimentation will be needed to attain the speediest and surest results. Can not the soil classifier and the agronomist work closer and closer together on this problem according to this plan? We are working, or should be, toward the same final results, namely, the betterment of agriculture, the perfection of farming systems, the maintenance of soil productivity, and the saving of the soil from disastrous washing. The soil is an extremely important factor in agriculture, although it is not the only one. Let's not overlook any important factor.

This is by necessity a rambling statement on a good subject. Please overlook its short-comings, remembering the circumstances under which the paper has been prepared.

5. THE VALUE OF THE SOIL SURVEY AS A BASIS FOR SOIL STUDIES AND SOIL USE

A. IN STUDIES OF SOIL PROPERTIES[1]

DISCUSSION BY M. M. McCOOL[2]

Those who have attempted to employ the soil survey as a basis for soil studies and soil use have found it to be of great value; yet it is no doubt true that the field work of the soil survey has not been exploited to its fullest extent in these lines. It is my opinion that in the future investigators working in the fields of horticulture, farm crops, farm management, livestock production and agricultural economics will make much greater use of the soil survey than is being done at present. It is probably well recognized that there is still a great need for continuous and systematically organized observations and studies of the physical, chemical and biological properties of the various horizons of the several soil types that have been mapped. It seems that this is essential if many of the results of scientific efforts are to be correlated and duplication reduced to the minimum, and it is recognized, by some workers at least, that this is the only way that the work may be systematized. As is well known, there are many workers who are interested in the development of soil science, and in order to accomplish this it is obviously necessary that much study will be concerned with the other matters than immediate practical aspects.

Inasmuch as I have only a few minutes to discuss this subject, it seems advisable for me to confine my remarks to an outline of the work which we are doing in Michigan, without burdening you with detailed results. In the first place, I should state that we are considering the soil profile as promulgated by Dr. C. F. Marbut in our investigations. We have considered it advisable and found it profitable to have descriptions and samples of various horizons that make up the soil types at our disposal. By careful selection of areas for the field work, we believe that we have described and have specimens of practically all of the soil types that occur in Michigan.

Certain physical properties of several of the important soil types have been studied. The water-retaining capacity of the different horizons that make up certain sandy soil types of northern Michigan, has been determined, by adding an excess of water to the surface of the soil and covering to prevent evaporation. After five days, samples

[1]Paper read as a part of the symposium on "The Utilization of the Soil Survey" at the meeting of the Society held in Chicago, Ill., November 13, 1923.
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were collected and the water retained determined in the usual manner. The results of these determinations are given in Table 1.

TABLE 1.—The water-holding capacity of northern sandy soil profiles

Type	Horizon	Per cent water
Mancelona	2 gray	7.74
	3 brown	12.01
	4	5.63
Emmet	2 gray	7.07
	3 brown	12.50
	4	5.29
Rubicon	2 gray	5.8
	3 brown	8.80
	4	4.67

In addition to the water-retaining capacity of the horizons the rate of water movement is under investigation, as is also the rate and distance of penetration of the roots of certain plants. We have observed that the roots of alfalfa plants have great difficulty in penetrating one of the horizons of the Fox sandy loam as evidenced by the irregular and twisted condition of the root development found therein. The layers above and below evidently do not impede root penetration, inasmuch as they show normal development. This may account in part for the comparatively slow growth of alfalfa in its earlier stages on this type of soil.

The relative colloidity of the horizons is determined by indirect methods, namely, the heat of wetting and the dilatometer. The former shows the amount of heat given off when soils are wetted and the latter the amount of water in soils that remain unfrozen when they are exposed to low temperatures. These properties are determined in the main by the colloids.

The barograph has been used to investigate the effect, if any, which various soil horizons have upon the permeability of soil profiles. It is interesting to note that in some instances the barometric pressure in the earth ten feet from the surface is the same as that at its surface, as shown by the fact that the curves obtained from these instruments so placed are identical. It seems that such investigations are fundamental in character, and that the soil survey or the classification of soils will be of assistance in correlating the results that we may obtain.

The total amount of several chemical elements in the different horizons of the predominating soil types are determined; not neces-

sarily with the end in view of estimating the amount of plant food elements that occur therein, but rather to determine if possible the causes for the conditions that exist in the soil profile. Interesting results have been obtained by this method of attack which we believe will have important applications.

The chemical reaction of the different soil horizons both in the laboratory and under field conditions is determined. These studies bring out very strikingly that great variations may exist in a soil profile and that the determination of the reaction of the surface few inches of soil may not and usually does not show the conditions to which the roots of the various crops or plants are exposed in their development. In fact, such methods of procedure may be misleading, as indicated by the conditions that we have found to exist in certain soil types. The surface few inches of Miami soils, for instance, show rather low pH values, but at comparatively shallow depths this is higher. This probably explains the fact that farmers generally can grow clovers and alfalfa successfully without the use of lime on these soils. The soil horizons of the Fox soils are usually strongly acid although the parent material is highly calcareous. Alfalfa fails on fields that have been long under cultivation without the use of lime; but it should be noted that a small application of lime suffices, the supposition being that when the roots of the plants enter the calcareous parent material the plant obtains a sufficient amount of lime for its growth.

In addition, the soil survey is being utilized as a basis for the collection of samples for determining the solubility of the various horizons in different solvents.

We have been able to utilize the soil survey to a great advantage also in our investigations on the use of commercial fertilizers to increase the productivity of soils. Field investigations on the Miami loam and silt loam show that the application of acid phosphate usually is the only profitable commercial fertilizer treatment. If, for example, there are 40,000 farms on a considerable portion of which the soil is of the Miami type, it seems that the soil survey or the location of these types is of tremendous importance to the state. On the other hand, we have found that Waukesha loam responds to fertilizers carrying nitrogen, phosphoric acid and potash, while Plainfield types respond to treatments of lime, nitrogen, phosphoric acid and potash. On some types, alfalfa responds vigorously the first season to applications of acid phosphate and muriate of potash, but subsequently little if any responses are noted. The indications are that the older plants obtain a sufficient amount of phosphorous and

potash from the subsoil, although a greater root development in upper layers may account for this. Other illustrations which show that the soil survey has been of tremendous value to us in our soil fertility work could be cited.

The soil survey has been made use of in making numerous lime-requirement maps and popular reports; both laboratory methods and field observations and investigations have been utilized in constructing these. We found that several soil types could be grouped together. Several of these were distributed about one year ago and the results from them have been very gratifying. We have likewise constructed maps showing the vegetable matter content of the soils of several counties.

Numerous farms and fields of different farms have been abandoned, temporarily at least, during the past few years. The soil surveys in several counties have shown that this abandonment is closely related to the soil type. In central Michigan, according to results of interviews with different landowners, the Plainfield types were the first to be left idle, followed closely by the Coloma and, subsequently, by the Fox and the Bellefontaine. As yet, we have found practically no abandonment of the Miami soils. When properly interpreted, such experiences should be of great assistance in the grouping of lands already in use, as well as those that are yet to be developed, and thus should be of great value in the formulation of state land policies.

It seems that there is a tendency to classify sandy soils along with those of finer textures. This is fallacious. It should be clearly understood that, in the classification of different soil types, sands should not be compared with the finer textured soils but should be compared with each other. It would be unjust to place all sandy soils in a lower grouping—such as second or third rate—than the finer textured ones. Farms having sandy soils may be well located so far as climate and market conditions are concerned and have a high agricultural value, although potentially such soils would not be considered to be as good soils as some of the finer textured ones. Instances are on record where the Plainfield and Coloma soils in southwestern Michigan which had been cultivated for a number of years under general farming systems were abandoned and, subsequently, were taken up and utilized for the successful production of grapes and other fruits. It certainly would have been unjust to have declared these types to be inferior or non-agricultural. Thus, in land classification where the soil survey is made use of, careful precautions should be taken not to misplace a particular soil type or a number of them, as future conditions may be such that the classification may be erroneous.

5. THE VALUE OF THE SOIL SURVEY AS A BASIS FOR SOIL STUDIES AND SOIL USE

B. IN EXPERIMENTAL WORK IN SOIL MANAGEMENT AND USES[1]

DISCUSSION BY E. E. DETURK[2]

When the soil survey of Illinois was begun twenty years ago, there was very little definite knowledge concerning the soils of the state. Just as the systematic organization and classification of the existing and accrued knowledge in any science is fundamental to the development of the science, so the systematic classification of the soils of the state was recognized as fundamental, both to the planning and execution of future soil investigations and to the most efficient utilization of land in agricultural practice. Thus, the soil survey has served as a method of classifying not only the soils themselves but also the knowledge obtained by the soil survey workers, concerning the various soil types as they occur in the field.

THE VALUE OF THE SOIL SURVEY IN INVESTIGATIONAL WORK

Knowledge which will make possible the better management of farm soils for increased, or more efficient food production, is obtained mainly through two types of investigation. These are: first, laboratory investigations, including physical, chemical and biological studies and greenhouse cultures; and, second, the experiment field. These two lines of investigation must, of course, supplement each other.

It is not appropriate at this time to enter into a discussion of the extent to which laboratory and field investigations contribute to the solution of problems in soil management. It is of value, however, to note some of the ways in which the soil survey aids in attacking soil problems in laboratory and field.

LABORATORY INVESTIGATIONS

In Illinois, the analysis of soil samples representing each soil type as it occurs in each county has been carried out as a part of the soil survey itself. This record of analytical data, together with the soil maps, serves as an "index" of the soils of the state, and by reference to it the soils which are best suited to a given investigation can be located. The following instance illustrates this use of the data.

[1]Paper read as a part of the symposium on "The Utilization of the Soil Survey" at the meeting of the Society held in Chicago, Ill., November 13, 1923.
[2]Assistant Professor of Soil Technology, University of Illinois, Urbana, Ill.

In a rather extensive limestone investigation which was begun recently, it was desirable to use in the greenhouse two soils, both as high as possible in acidity but at the same time having the widest possible divergence in organic matter content. By the combined use of the soil analysis records and the soil survey mapping records, the best soils available for this purpose in all the fifty-odd counties which have been surveyed and from which soils had been analyzed up to the present time were readily located.

It is realized that the "index" is not perfect, and sometimes directs us to the wrong "page." For instance, in a search for a soil which would be especially responsive to phosphate treatment, one was selected which contained only 0.018 percent of phosphorus, or 360 pounds of this element in two million pounds of surface soil; but testing it in the greenhouse, no response to additions of any form of phosphate could be secured.

The record is not only of value in locating soils for certain experiments, but the information thus recorded concerning the more important agricultural soils aids in pointing the way to research problems which should be undertaken.

Field Investigations

In the use of soil experiment fields, the soil survey and the methods which have been developed through its growth are of great value in at least the two following respects:

Management and study of present experimental fields.—The University of Illinois now operates thirty-eight soil experiment fields distributed throughout the state. For the most part, these particular fields were selected and used for experimental work because they were either given to the University by interested landowners or "loaned" for experimental work for an indefinite period, as long as might be needed. The question of the suitability of the soil of a particular field for experimental work was a minor factor in determining the exact location of most of these fields, although the dominant soil type to be represented by a given field was determined by the University. This procedure was justified by the fact that the small funds available limited the choice to free fields or no fields. By means of soil survey methods, the soils of all experimental fields are now being mapped in detail so that the distribution of all the soil types and phases in each experimental plot is indicated. The information thus secured is of value to the experimenter: (a) in interpreting the results of fertilizer or other treatments applied; (b) in determining the feasibility of replanning or modifying experiments already under

way; and (c) in distinguishing among the present fields those which, due to extreme soil variability, are unsuitable for experimental work and hence should be discontinued and those which are sufficiently uniform to be continued, even though with modifications in some cases.

Location and planning of new experimental fields.—Through the soil survey, the location, extent and agricultural importance of the major soil areas of the state have been made known. Based upon this information, it is possible now to determine with some degree of accuracy the strategic points for the location of major experimental fields upon which are to be carried out investigations bearing upon the more fundamental soil problems. This was not possible at the time when most of our present experimental fields were located. These fields should be maintained for a comparatively long time. In addition to the major fields, an adequate plan of soil study requires the operation of a number of minor fields which may be located in areas of lesser agricultural importance, or planned in order to solve local or special problems which may not affect large areas. In many cases, the minor fields may be discontinued after a few years. Some may even take the form of cooperative field tests.

With this point of view, the attempt has been made to look into the future far enough to plan tentatively the location of the major fields and a few of the minor ones which will be needed. Eight major and eight minor fields have thus been tentatively located. It may be said, however, that none of the above fields have been provided for financially or exactly located, and the scheme represents aspirations rather than definite plans.

In the determination of the exact location of the field, the methods of the soil survey again come into valuable service in eliminating areas of marked soil variability. Thus, areas, which under a less rigid inspection would have been passed, may be entirely eliminated from experimental use. The laying out of the field for experiments is based upon the same requirement for soil uniformity as is the selection of the field. Experimental plots should not cross soil type boundaries. The Illinois soil investigators have reached a definite agreement that in the future no new field shall be used for plot experiments unless all of the soil of the area for the plots of a given experiment shall be of the same type, and that, so far as is possible, all the soil of such area shall be of the same phase of the type.

It is recognized that the soil type is not a perfect standard for the determination of soil uniformity for experimental work. Even the restriction of a field to a single well-defined phase of a type does not

insure uniformity. The attention of agronomists was called to the marked variability of apparently uniform soils by Wood and Stratton and others more than ten years ago.[3] It may profitably be supplemented by the application of chemical, biological or physical tests. In any case samples of the soil of each plot should be taken for chemical, physical and possibly biological examination before experiments are begun.

THE VALUE OF THE SOIL SURVEY IN THE UTILIZATION OF SOILS

Aside from its value in soil investigations, the survey is of direct benefit to the farmer himself and to other agricultural interests in many respects. The following are some of the more important uses which it serves:

Value to the Farmer

"Stock information" concerning soil management practices is not in the possession of farmers to the extent which is usually assumed. Such information finds a ready channel for distribution through the published soil survey report. An advantage of the soil report over the station bulletin, in this distribution of information, lies in the possibility of sorting the information, and presenting or emphasizing only that which is applicable in the county concerned. Furthermore, direct applications are made to the individual soil types as they exist in that locality.

The general educational value of the soil report deserves consideration. This value has been utilized in Illinois by making the introduction of a new soil report into a county the basis of a two-day or three-day "soil fertility school." One or more (usually two or three) men from the soils staff of the agricultural college arrange through the farm adviser for public meetings at various points in the county. These meetings afford opportunity not only for explaining the soil survey and showing the farmer how he can utilize the soil report to the best advantage, but also for arousing interest in the problem of soil management and agricultural production in its broader aspects. Attention may be called to unsolved problems, the investigation of which may be under way. It is encouraging to note the interest which is shown, even by the more lethargic man, when he finds that the state has taken sufficient interest in his own farm so that now he can identify the different kinds of soil upon his own farm by means

[3]Wood, T. B. and Stratton, F. J. M. The interpretation of experimental results. *In* Jour. Agr. Sci. (London), 3:417–440. 1910. And Mercer, W. B. and Hall, A. D. The experimental error of field trials. *In* Jour. Agr. Sci., 4: 107–132. 1911.

of the map and then turn a few pages to specific suggestions for the treatment of these particular soils.

In addition to the published reports, unpublished records of the survey are used almost daily in answering the inquiries of farmers from all parts of the state.

VALUE TO THE FARM ADVISER

The farm adviser has opportunity to use the results of the soil survey from the start. The mapping of a county is followed immediately by the preparation of a hand-made copy of the soil map for the use of the farm adviser. Likewise, a copy of the soil analysis data is furnished to him upon request, as soon as this phase of the work is completed.

VALUE TO PROSPECTIVE BUYERS, APPRAISERS AND OTHERS

Prospective land buyers find in the soil report accurate descriptions of farm land with respect to factors which are of very great weight in determining its agricultural value. Land banks, land agencies, farm loan associations and similar organizations make considerable use of soil reports amd maps for appraisal purposes. Soil survey records are also occasionally called into use in litigation.

5. THE VALUE OF THE SOIL SURVEY AS A BASIS FOR SOIL STUDIES AND SOIL USE

C. IN THE TEACHING OF SOILS IN COLLEGE[1]

DISCUSSION BY FIRMAN E. BEAR[2]

In teaching the course in Soil Management, which is required of all students taking the course leading to the B. Sc. degree in the College of Agriculture of Ohio State University, it has been the policy to require each student to bring a sample of soil, selected according to directions furnished him, from his home farm, for purposes of laboratory study. In this study, the student determines the percentage content of nitrogen in his sample of soil; its reaction, and if acid its probable limestone needs for the cropping system employed; its nitrifying efficiency, with and without the addition of calcium carbonate; its *azotobacter* content; the soil class to which the sample belongs; and its probable type as determined by comparison with typical samples of the various types on display in the laboratory and from a knowledge of the location from which the sample was secured.

[1]Paper read as a part of the symposium on "The Utilization of the Soil Survey" at the meeting of the Society held in Chicago, Ill., November 13, 1923.
[2]Professor of Soils, Ohio State University, Columbus, Ohio

It happens that a fairly satisfactory reconnaissance soil survey has been made of the entire state of Ohio and that detailed surveys have been made of representative counties in various parts of the State. Thus it is possible to check the students' classification of the samples which they bring into the laboratory by knowing the location from which they came and by experienced examination with the thumb and finger and the eye. The chemical studies indicated above are of additional value in this connection.

Since the number of students taking the course is from 150 to 200 per year and since these students come from almost every county in the state, several representatives of each of most of the prominent soil types are to be found among their samples. By arranging the data secured from laboratory examinations of these samples, as it is handed in on report cards by the students, on a chart placed on the bulletin board in the laboratory, the students, from a study of this chart, gradually come to appreciate the significance of the series names and to have a fairly definite conception of the meaning of the soil survey maps, both the reconnoissance maps and the more detailed county maps.

In preparation for their laboratory study, the samples are dried and pulverized to pass a 10-mesh sieve, the gravel being discarded. Part of each sample is placed in a 16-oz. screw-capped glass jar; the remainder of the sample is then pulverized to pass a 100-mesh screen and this portion is placed in a smaller jar of the same design. This work is done for the students by the laboratory assistants according to a standardized procedure. The soil samples, neatly labeled, are passed out to the students, who find considerable interest in comparing their own samples with those of their associates. As the work of the quarter proceeds and as the laboratory chart becomes filled with data, there is a very noticeable increase in the interest of the students in their work with these samples.

More recently, it has been thought desirable to make a permanent collection of the more important soil types of the state and in much larger amounts than are to be had in the usual laboratory collections. It was finally decided to outline a miniature state of Ohio, on a portion of the experimental field nearby, and to place within this area samples of the various soil types located in positions corresponding to those in which the soils are the predominating types naturally. For this purpose 160 large sewer tiles, having diameters of 24 inches each, are being arranged in 40 groups of four each. Each group of tiles is being filled with a prominent soil type, and is so placed as to indicate

the location of the soils within the state. The samples are being taken to a depth of 24 inches by natural horizons, or layers, which are being placed in similar positions in the tiles. Each of these tiles is buried in the soil up to within a few inches of its top. The soil types contained in the tiles are placed immediately on top of the subsoil exposed by excavating in placing the tiles in position. Each tile holds approximately 500 pounds of soil and subsoil.

Fortunately, the city of Columbus is so located as to be accessible, by good roads, to almost any portion of the state and the soil can be hauled by truck from its natural location to its new position with little delay before it is placed in the sewer tiles. Of the 40 soil types found in this state, six were placed in position in 1923. A similar number is expected to be brought in each year until the collection is completed.

The purpose of this collection is to provide for the students, and for investigational purposes, a collection of the soil types of the state. These may be studied as to their superficial characteristics, by the students, at any time during the year and, as to their relative productive capacities for a standard crop rotation, during the growing season. The soil in the first tile of each soil type will be given no fertilizer treatment; that in the second will be given a standard application of limestone; that in the third will receive phosphate in addition; and the soil in the fourth will be treated with a complete fertilizer. A four year rotation of corn, oats, clover and wheat (with sweet clover) will be followed. It is believed that by this method the students, as well as the visitors who are interested, will be able to fix fairly definitely in their minds the characteristics of the various soil types and their locations within the state, and that they will gain some idea as to the relative productive capacities of these soil types for the crops grown.

6 A. THE UTILIZATION OF THE SOIL SURVEY IN CROP EXPERIMENTAL WORK[1]

Discussion by W. L. Burlison[2]

Dr. E. W. Allen,[3] in his address as Vice-President of the Agricultural Section, American Association for Advancement of Science, in December, 1921, said that "certain types of work have not been marked by growth, vision and method, with the result that conclusions drawn from them are of doubtful scientific value." He indicated his belief that "we have not yet learned how to interpret, except superficially, the answer which the soil and the plant give as just what has happened or what the apparent effect is due to, we have not yet learned how to examine a plot of soil so as to determine the changes occurring from time to time or brought about by long continued systems of treatment, or how to connect these changes with the response of the crop in a given season or period. Indeed relatively little study is now given in such experiments to the soil itself, and only to a limited extent are underlying questions suggested by such experiments being intensively studied." A statement of this character coming from Dr. Allen is worth more than a brief reflection. It calls for a pretty thorough examination of any line of research, especially in crop production, a subject which deals particularly with climatic and soil factors in their most complex form.

Studies in the field performance of crop varieties, or strains, have been planned in a sort of haphazard way, with no very great thought of the accuracy of the results. It is not at all uncommon to find published data which are based on only two or three years' work and from only a single plot in each season. Cultivation experiments on corn have been long continued, yet it is well nigh impossible to draw reliable conclusions because little or nothing is known of the life cycle of the corn plant. A vast amount of money has been spent on corn diseases, but today progress is handicapped because the soil physicist and biologist were not called in time. The whole crop disease problem seems at times to be so tied up with soil problems that one may question whether or not the task belongs to the soil research worker as much as it does to the plant pathologist. At any

[1]Paper read as a part of the symposium on "The Utilization of the Soil Survey" at the meeting of the Society held in Chicago, Ill., November 13, 1923.

[2]Head of the Department of Agronomy, University of Illinois, Urbana, Ill.

[3]Allen, E. W. The method of science in agriculture, *In* Science, n. s. 55:6–11. 1922.

rate, it is quite clear that the soil has a very significant influence on the pathological problem.

A study of projects in crop production gives one the feeling that the "mere accumulation of data" is the chief end in view. It is well to admit that much of agronomic work is of "an elementary nature" and based largely on observation, and that rarely is there an attempt to get at the fundamental underlying principles having to do with plant growth and plant relationships.

There is room for little argument on the points which Dr. Allen raises. It is well to admit them without discussion, because they give such a very fine place to begin to recast the form and plan of work. There seems to be a growing desire to strengthen the many weak spots in plant investigations which Dr. Allen has so helpfully set down.

Last summer, a corn-belt section of this Society was organized for the express purpose of studying critically the investigations which are now under way in the central states. The first meeting of the new group was held at the University of Illinois. Almost two days were devoted to a study of the work of the Agronomy Department of that institution. Clearly, methods of field investigation were the point of greatest interest. The planning of crop experiments from the standpoint of uniformity of soil type, plot arrangement, replication, etc. seemed to attract a great deal of attention. More freely than ever before the workers discussed their problems with their fellow workers. Each one seemed to be looking for help from whatever source it was available.

These things mean that the outlook for a new order in research methods is taking a substantial hold. From all sides comes word that crops men are joining hands with the plant pathologist, the plant physiologist, the chemist and the physicist. In other words, the day of team work is dawning. Without doubt much good will come from these joint efforts. Many mistakes could have been avoided in the past if crops workers had called upon a fellow worker in the field of science. This brings me directly to the topic which I am to discuss.

No attempt will be made to measure exactly how helpful the soil physicist may be, but an endeavor to point out how crops investigators and the soil physics workers are co-operating in planning field work in crop production. Specific illustrations will serve well this purpose.

Some years ago, the Alhambra crops field (a tract of forty acres of land), was given outright to the University of Illinois for experimental work. Of course, "we had to take it." The soil is classified as brown

gray silt loam on tight clay. Such a soil is very nonuniform. Many so-called scald spots may be found in this tract. For the first two years soybeans were grown on the field with quite satisfactory results, but with considerable variation in different plot yields. The yields on certain plots were almost double those on others. It was not until oats were seeded on the tract that the irregular nature of the soil showed up fully. When the oat crop was about three inches high, the plants on certain plots began to die and before the end of a two-week period the crop was a discouraging sight. After consultation, it was decided to recommend to the Dean of the College the dropping of experimental work on this field; but on going over the problem it was learned that these "scald spots" are typical of the type of soil which is called brown gray silt loam on tight clay. Since this was the case, and there is a large area of this type in Illinois, it seemed to be wiser to continue the experiments on this particular tract of land. The task which remained was to plan checks and replications so that the work might be carried on in such a way that the results would be reliable. The division of soil physics has made a detailed soil map of the field and has recommended to the crops section the arrangement which is best suited to overcome soil variation. Plots will be placed with reference to soil types rather than with reference to the north star.

An illustration from the Palestine soil experiment shows how the soil survey prevented the making of a second mistake similar to that just mentioned. A study of the fertility results from this experiment would lead one to believe that there is great difference in the soil type, but a glance at the soil map shows that there is uniformity throughout the field. Such differences must be looked for in soil of the character clearly shown by the survey.

Experience on another soil experiment field may be cited as an illustration of a different type of assistance which the soil survey may give. The Sidell field has presented certain difficulties in the matter of interpreting the results obtained from that field. Just recently a detailed survey of the tract has been made and four rather distinct types recorded. Just what to do here is a real problem. It is doubtful if the plots could have been arranged in such a way as to overcome soil differences. It is quite certain that in the future no field will be accepted when there is as much soil variation as there is in the case of the Sidell field.

The Pana soil experiment field presents in a very striking way the value of a soil survey in planning plot arrangement. Two principal

soil types are represented in this field. There is a marked difference in the yield of crops grown on series 100 and 400. To obtain most accurate results plots in series 100 should be repeated in series 400. Possibly, if the work is carried on through a long period of years, the difference will be overcome, but there is some doubt that many years of repetition will overcome all the trouble.

The Urbana crop field holds certain interesting features. The southwest rotation has three phases of brown silt loam within an area of 16 acres. It is too late now to rearrange the plots, but it is not too late to make use of the soil survey in interpreting the results. The plots of series 300 nearly always give the best yields obtained from the four series, while those of series 100 stand at the low end of the list. A glance at the map shows that the soil of series 300 is black clay loam, the very richest soil of this state, while that of series 100 is a light phase of brown silt loam. These are facts which are decidedly worth knowing when one is studying the crop returns secured from this rotation. Certainly, difficulties are arising in interpreting the results of this rotation because of soil variation.

One may quite naturally ask the question, "does a field uniform in type tell the full story?" As early as 1909, Dr. L. H. Smith reported certain field results which will throw some light on this question. The records were taken on "a field that had been sixteen years in pasture, which was broken up in 1895 and laid out into plots to be subsequently used for soil experiments. The land is slightly rolling but otherwise quite uniform in appearance. There are in the series to be considered in this connection 120 one-tenth acre plots. These plots were all planted to corn for three consecutive years without any soil treatment, so that the records offer a rather exceptional opportunity for a study of this kind." In 1895, the range of variation in yield of corn was 54 bushels per acre. In 1896, it was 104 bushels per acre; and in 1897, 80 bushels per acre. Dr. Smith points out that "plots lying adjoining have shown the following maximum variation: 1895, 18 bushels; 1896, 11 bushels; 1897, 8 bushels." He adds that: "The above results give us a conception of the unaccountable plot variation which we have to deal with in field tests. The possibility remains that a still closer study might detect some abnormal factors at play to account for these variations in certain cases, but the study certainly suggests the importance" of a careful study of the field before comprehensive and expensive experiments are put under way.

This work indicates clearly the need of a more detailed study of the soil than is ordinarily included in the usual type of soil survey work.

There are some indications that, in addition to the soil type, certain other soil characters should be obtained before starting field work which is to continue over long periods of time, namely, the chemical, physical and biological nature of the soil.

For about six months, Dr. R. S. Smith has been seeking for a field near Urbana which might be suitable for crops experimental work. He has tramped over the section quite thoroughly without very encouraging results. No field will be accepted by any division in the agronomy department which is not at the very outset approved by the division of soil physics.

In planning crop production field investigations, the help of the division of soil physics is necessary if the work is to be fundamentally sound. If plans which are now under way are carried through, any field used for agronomic work will be examined in the following way: (1) the soil of the field will be surveyed and mapped in order to determine its uniformity; (2) if found suitably uniform in soil, the contour will be determined; (3) plots, check, etc. will be so arranged as to overcome soil differences; (4) A study of the chemical and biological nature of the soil will be made as far as possible; and (5) soil samples will be taken for determinations of nitrogen, phosphorus, and potassium content.

It seems now that if dependence is to be placed in field tests every precaution should be taken to insure their accuracy. This means that there must be known as nearly as possible the nature of the soil and what is going on in it from season to season. Added to this, there must be a sufficient number of plot replications extending over long periods of time.

6 B. UTILIZATION OF THE SOIL SURVEY IN CROP EXPERIMENTAL WORK[1]

Discussion by C. A. Mooers[2]

In this brief discussion I have in mind only such conditions as are found in Tennessee and similar parts of the South where residual soils predominate. Unfortunately, I am not in the possession of the experimental evidence which would enable me to speak with full assurance on all phases of the subject. The Tennessee agricultural experiment station has, however, conducted numerous crop experiments on widely different types of soil and out of the accumulated

[1]Paper read as a part of the symposium on "The Utilization of the Soil Survey" at the meeting of the Society held at Chicago, Ill., November 13, 1923.
[2]Director, Tennessee Agricultural Experiment Station, Knoxville, Tenn.

data I will try to draw such conclusions as I have reached during my experience of the past thirty years.

THE FACTOR OF SOIL REQUIREMENT

The reports of the Bureau of Soils surveys describe general productivity conditions, but do not attempt to give the soil requirements, other than to make such simple suggestions as appeared appropriate to the survey workers. Suggestions of this kind, as well as indications reached from wire basket experiments, have not proved of special value, but they may call attention to the need of further information. When, however, the soil requirements have been determined at even one representative locality, the soil survey becomes doubly useful in the making of crop recommendations elsewhere on that same soil type, for regard must always be had to the crop requirements. Alfalfa has a high lime requirement. Lotus, a legume resembling alfalfa in general appearance, has a low lime requirement. The lime requirement of crimson clover is less than that of red clover, which in turn is less than that of alfalfa. Barley thrives on an abundance of nitrogen and will make good use of an amount that would be too much for either wheat or rye. Hence, considerable caution must be exercised in the making of recommendations, both as to crop adaptability and special soil requirements; for soils of similar color and texture, but originating from the decomposition of different geologic strata, are apt to differ appreciably in plant food requirements. Also, soils of the same origin vary with the lay of the land, the kind of farming that has been practiced and the length of time under cultivation. For these reasons, crop experiments under a number of different conditions may be necessary in order to determine both what crops are capable of being advantageously grown and what varieties should be used on an area as surveyed.

CROP AND VARIETAL ADAPTABILITY

That light soils are especially well suited to truck crops and that heavier types are preferable for wheat and grass, has long been known. Outside of similar broad generalizations, however, the special adaptability of a crop to a special texture of soil seems to be a matter of uncertainty. For example, Burley tobacco is being successfully grown on rather widely different soils in Tennessee and Kentucky. Apparently, any one of several soil types is as good as another for this crop, provided that proper attention is given to the requirements of the crop, an important factor being an abundance of plant food of all kinds; in other words, Burley tobacco is primarily a rich-land

crop. As a somewhat different example, alfalfa is generally considered to be a rich-land crop, but at the West Tennessee experiment station, on a silt loam of only moderate productivity when planted to non-legumes, the yields of alfalfa are greater and the crop more certain of success and long life than on other and apparently similar silt loams, even when the latter are more productive as measured by the yields of non-legumes. Perhaps subsoil conditions may explain the difference. While the soil survey may be of material assistance in demarking the limits of areas naturally well adapted to a crop, it is not necessarily of noteworthy utility in this respect to the farmer, especially in a long-cultivated section, where most crops have been tried out and the results are common knowledge. If investigation by the experiment station or any other agency shows how to make a success of a crop previously considered not to be adapted to the soil, a brief soil description in the bulletin or report may prove to be sufficient for practical use, but the value of a soil survey to which reference could be made is apparent.

The results obtained by the Tennessee experiment station in varietal trials of corn, as conducted for a number of years on various soil types, show conclusively that varieties vary greatly in their adaptability to soils which differ in productivity. That is, in terms of extreme conditions, there are rich-land and poor-land varieties. At the outset of this work, I thought that there might be some correlation between soil type and varietal adaptability, but at present I do not see any such relationship except as it concerns degree of productiveness. That is, if a half dozen varieties yield in a certain order on land which is capable of producing in the neighborhood of 30 bushels of corn per acre, I would expect them to give yields in the same order on any other soil type of similar productivity. What is true of corn is probably true of many other crops.

This subject is of much practical importance and merits, I believe, greatly increased attention. At the Tennessee experiment station, the opinion that the productivity of a soil is usually the major factor in controlling both crop and varietal recommendations has been greatly strengthened in the past few years. Also, this point of view simplifies and explains much data that at first sight appear to be conflicting.

OTHER IMPORTANT USES OF THE SOIL SURVEY

Some applications of the soil survey have been mentioned, but there are other important uses. One of these is the discovery of areas which have not been called to the attention of the crops department.

If the soil survey completely covered Tennessee, I have little doubt that it would disclose types of soil on which no station experiments had been conducted.

Another asset of the soil survey lies in the naming and thereby making more definite the soil type on which crop experiments have been made. By this means, results obtained at widely separated points can be compared, and workers in other states are much better able to interpret and utilize them than would otherwise be possible.

HOW THE SOIL SURVEY IS PROVING MOST VALUABLE TO NORTH CAROLINA[1]

C. B. WILLIAMS[2]

At present serious problems are confronting farmers of North Carolina. But perhaps none other is of as great economic importance as is that of the building of the fertility of their soils by economic means. In order to carry on soil investigations systematically and logically in any state, it is necessary to have the different types of soils mapped, analyzed and described. The mapping and analyses of the soils are as basic in soil investigations in any state as is the carrying on of the field work, because it will not be possible to conduct the field work most intelligently and apply the results most rationally unless one knows the soil conditions and their deficiencies in the different counties of the State. The soil survey furnishes the data that are needed in applying the results of the field investigations, both with soils and with crops.

North Carolina (in 1899) was one of the first of the states to take up the study of its soils in this systematic way.

In this state, all experimental work with fertilizers and in variety tests and for improvement of crops is carried on with reference to soil types. At first, the larger and more important types were selected for the location of the branch stations and the outlying fields. Later on, as rapidly as funds have been available for carrying on the work, it has been extended to the important agricultural types of the State. Working under such a plan, after definite information has been secured from the field, it has been found that the results may be applied quite safely in a general way to the soils of nearly all farms located on

[1]Contribution from the Division of Agronomy, North Carolina State College of Agriculture and Engineering, Raleigh, North Carolina. Read at the meeting of the Society held in Chicago, Ill., November 13, 1923.
[2]Chief of the Division.

the same type of soil, regardless of how widely separated within the state the soils of the same type may be from the one on which the experiments were conducted.

The following are some of the ways in which the soil survey has proved to be valuable to different classes of people and for different purposes in this state.

1. *To agricultural workers:*

(a) It has provided county agents and extension workers with definite first-hand reliable information with reference to the general agricultural conditions existing in the county or section in which they are working.

(b) It has provided all agricultural workers with a definite basis on which to apply results that have been secured in experimental work on different types of soil.

(c) It has provided the definite information which farmers are demanding at the present time from station and extension workers. The soil survey reports, together with auxiliary publications, are the main sources from which this supply of information is drawn. The extension worker must not only refer the farmers to these publications, but in many cases it is his duty to interpret and to help the farmers to apply correctly the information which they contain.

2. *To all farmers:*

(a) It has insured that a farmer who is operating on a certain type of soil need not spend his time and money experimenting on some problem which has been worked out many years before by someone connected with the state or federal departments of agriculture.

(b) It has given to a farmer who is writing for information a method of describing his soils so that they can be identified by the person to whom he writes, and so made it possible to advise him intelligently and reliably with reference to the best plans to follow in the treatment and management of his land for different crops.

(c) It has insured that the results which have been used as a guide in answering an inquiry from a farmer are absolutely applicable to the conditions which prevail on the inquirer's own farm.

(d) It has made it possible to take the results from our branch experiment farms and apply them directly to the farms which have the same character of soils located anywhere else in the state.

(e) It has given to those who are growing specialized truck or farm crops a basis of knowledge as to where they may find soils of the type adapted to these crops in their own communities or elsewhere in the state, if they should desire to extend their operations or move from

one locality to another, and has supplied the state agricultural experiment station with information on the basis of which it may advise with reference to why certain communities or sections are specially adapted to the growing of particular crops.

3. *For county advertising:*

The soil survey reports aid in advertising the resources and opportunities in any county:

(a) By presenting a picture of the county or area in the form of a map; and

(b) By giving a detailed and unbiased description of the operations, industries and resources of the county.

In many cases such organizations as boards of trade, chambers of commerce, or civic clubs could very well afford to reprint these reports for wider distribution, in order to attract new settlers.

4. *To home seekers:*

The soil survey offers definite and reliable information about any particular section and its possibilities in the following matters, and so aids them:

(a) To decide what section they prefer to locate in by giving them definite information with reference to climate, soils, adaptation to crops, transportation facilities, market facilities, etc.;

(b) To decide what kind of crops they should grow in their new location, varieties of these crops, methods of cultivation, and methods of building up and maintaining a high state of fertility of their soils;

(c) To guard themselves against the operations of crooked land agents; since the report sets forth the prevailing price of lands of a certain character, informs the prospective purchasers as to the development that has been made on certain soils in certain sections, and discusses labor conditions and markets.

5. *To county commissioners:*

The soil survey map is helpful to county commissioners:

(a) For general reference;

(b) As an aid in determining whether or not a certain road should be made public, by showing the extent of development of that particular section, the distance from other public roads and character of drainage;

(c) By making it easier to plan and construct new roads;

(d) By acting as a reliable guide for land assessors. (In one county, an engineer actually copied the soil survey map and sold it to the county commissioners as his own work.)

6. *To county superintendents of education:*

The soil maps help county superintendents of schools:

(a) By showing accurately the location of all schools in each county;

(b) By indicating whether or not a new school should be established in any particular section from which a petition may come;

(c) By indicating whether or not certain schools should be combined.

7. *As an aid in making other surveys in the counties of the state:*

The soil survey map is found valuable in making other surveys, such as:

(a) War maps, giving details of all waterways, bridges, roads, railroads and canals of the entire state;

(b) Special reports of any kind by civil engineers, such as best location for the public roads of the county;

(c) Reports for bridge construction companies;

(d) Health, educational, farm-life, social service and other surveys.

8. *To teachers of agriculture and sciences.*

(a) By aiding the teacher to know something about the soils and farming on the farms of the patrons around the school so that it can be taught in the schools;

(b) By helping the teacher to explain to the children the extreme importance of a soil survey map;

(c) By helping the children to become familiar with the main characteristics of the leading soils of the community and thereby lead them to an increased interest in the soils and general agricultural conditions throughout their county;

(d) By indicating the location of other schools of the county, also the names of streams, school houses and churches;

(e) By giving the children a necessary knowledge about local conditions and thereby broadening and practicalizing their education.

9. *To manufacturers and lumbermen:*

Men engaged in these industries have found the soil survey reports very valuable, because they give:

(a) The location of waterways, roads and railroads;

(b) An intelligent discussion of local factors and designate places that would be suitable for the establishment of manufacturing plants;

(c) Information with relation to the water-power that may be developed;

(d) Information with reference to the convenience of transporting raw materials to, and manufactured products from, the plants.

10. *To real estate agents:*

Real estate dealers find that, upon familiarizing themselves with the soil reports, they

(a) Can more safely and intelligently describe lands to prospective buyers;

(b) Can advertise farms more accurately for prospective buyers;

(c) Can give definite and precise information with reference to soils, crops, etc., to all of those who are seeking information with the hope of finding a suitable location to settle.

11. *To travelling men, canvassers, and tourists:*

These classes of people find the soil survey reports very helpful:

(a) In determining what are the shortest routes through a county or area;

(b) In the location of roads from all cities, towns and postoffices;

(c) In the location of streams and main highways;

(d) In the location of dwellings and their distance apart or from railroads.

12. *To the United States Postoffice Department:*

In many cases, postoffice inspectors have depended upon the soil maps attached to soil survey reports, when they are available:

(a) In measuring and laying out rural routes;

(b) In planning new routes intelligently and expeditiously;

(c) In saving the expense of making route maps.

13. *To farm loan and other banks lending money on farm lands:*

All institutions lending money on farm lands have found the reports valuable in the following respects:

(a) They put in the hands of the appraisers definite information with reference to agricultural conditions in any county or section of it.

(b) They give the appraiser definite information with reference to the soils and their agricultural value of the county.

The federal land banks have depended largely upon the information contained in the soil survey reports and maps in appraising agricultural lands for loans to farmers.

LAND COVER STUDIES AS A BASIS FOR A MORE ACCURATE INTERPRETATION OF THE SOIL SURVEY[1]

M. Francis Morgan[2]

INTRODUCTION

Soil surveys are in progress in many states of the Union. Within a few years more than half of the land area of the country will be mapped to show general soil conditions, as far as these can be determined through a method of classification such as has been developed by the United States Bureau of Soils. At this moment, it appears doubtful that other lines of investigation have kept pace with the survey in their contributions to the development of a more accurate knowledge of soil relationships. The soil survey can show the distribution of soils of certain characteristics. It remains to the agronomist, the ecologist and the forester to show how best to use them, else the millions of dollars expended in soil survey work will be of little avail.

Some mistaken conceptions may have contributed to the somewhat chaotic condition which now exists in regard to an interpretation of the soil survey. The tendency has been to consider the use of the soil map by the individual farmer as the primary object, and the reports have been shaped in the light of this view. In actual practice, twenty-five years of effort has failed to reach more than an insignificant number of the farmers in the areas surveyed, while scientists, extension workers and other students of the soil of a given region have limited themselves to a very superficial and elementary discussion of the real nature of the soils mapped. Is it merely a lack of publicity that has caused farmers to ignore the survey? The limitations of the soil map, as applied to a particular field on the farm, are apt to lead the farmer to very erroneous conclusions if he attempts to use it as a guide to soil management.

Furthermore, the soil survey has made no claims of usefulness as a guide to soil productivity. Little attempt has been made to correlate soil type with plant growth. Perhaps this is beyond the proper functioning of the Bureau of Soils. It has been stated (5)[3] that it is not generally possible to classify soils by the things that grow upon them and this has led to the inference that little correlation can be made between the soil and the plant.

[1]Contribution from the Department of Soils, Connecticut Agricultural Experiment Station, New Haven, Conn. Received for publication April 26, 1924.
[2]Associate Professor in charge of soils research.
[3]Reference by number is to "Literature Cited", p. 458.

Efforts, such as those by Pendleton (4), have been made to correlate productivity with soil type, through chemical analyses and fertilizer experiments. In Ohio (7) and elsewhere, the soil types represented on the various experimental fields have been given due consideration in interpreting results. The importance of such correlations has been pointed out by Brown(1). Frequently, a failure to recognize that any sample or plot from a mapped area is truly representative of that soil type has resulted in very irregular conclusions. Some states, notably Illinois (2), have made very detailed soil maps of their experimental fields, and something really valuable can be expected in the future along this line.

The survey workers in the field have not altogether disregarded the ecological significance of soil type; but the nature of their work has limited them to a few casual observations, with no effort to accumulate data in support of the conclusions which they have reached as to the typical flora of a given soil.

In connection with forestry, Veatch (8) and Kelly (3) have made studies on the tree associations on various soil types. This work shows the possibility of such a line of investigation.

Thus far the one notable attempt at a correlation of soils with land cover has been in the work of the land and economic survey in Michigan (6); but it must be remembered that their soil studies were but incidental to a predominantly economic project.

Connecticut, with an agricultural history of more than two centuries, with some very intensively farmed areas, yet with many tracts which have always been in forest, or which have been in pasture long enough to revert to a stable condition as to flora, offers certain peculiar advantages in a study of land-cover relationships.

During the past season (1923), something of this sort was attempted in connection with a broader project of the survey of both soil and economic factors which have contributed to the present adjustment of agriculture in a typical New England town. A belief that the soils phase of the above survey, altho of a limited application, will contribute something to a clearer conception of the importance of this type of investigation has prompted the writer to submit this brief summary of the above work.

PLAN OF WORK

The town of Lebanon, with purely agricultural interests, settled prior to 1700, and located in the central portion of the "eastern highlands" of Connecticut, was selected for the above survey. The area had been mapped by the Bureau of Soils in 1911 as part of the

Table 1.—*Description of important soils in Lebanon soil type—land cover survey.*

	Mode of formation	Parent rock	Substratum		Subsoil color	Surface color
			Structure	Color		
Gloucester stony fine sandy loam stony loam fine sandy loam loam	glacial till	granite-gneiss usually light in color	loose	gray	dull yellow	medium brown
Charlton stony fine sandy loam stony loam fine sandy loam loam	glacial till	dark colored schists and gneiss	compact	greenish gray	dull yellow	dark brown
Whitman stony loam	glacial till	granite-gneiss and schists	very compact	blue gray	mottled gray	gray black
Hinckley gravelly sandy loam	glacial kame and esker	granite-gneiss and schists	loose gravelly	grayish	dull yellow	light brown
Merrimac fine sandy loam	glacial terrace	granite-gneiss and schists	loose gravelly	grayish	dull yellow	medium brown
Podunk loam	alluvial	granite-gneiss and schists	indefinite	——	dark brown	gray black
Meadow	cumulose	indefinite	indefinite	——	black	black
Muck	cumulose organic	indefinite	indefinite	——	black	black

TABLE 2.—*Land cover distribution of important soil types in the Lebanon land cover—soil type survey.*

Soil types	Total area (acres)	Tilled land or mowing Percent	Clean pasture Percent	Low grade pasture Percent	Brush pasture Percent	Common hard-woods Percent	Swamp hardwoods Percent
Gloucester							
stony fine sandy loam	12,342	4.3	10.5	9.3	8.7	67.2	—
stony loam	943	3.9	6.1	25.1	10.5	54.4	—
fine sandy loam	7,208	32.1	9.3	9.1	4.7	44.8	—
loam	922	21.3	19.2	10.6	12.0	36.9	—
Charlton							
stony fine sandy loam	1,134	13.4	25.8	17.1	16.2	27.5	—
stony loam	1,110	18.1	33.2	13.2	10.4	25.1	—
fine sandy loam	3,492	50.0	19.3	7.4	2.9	22.4	—
loam	2,660	62.7	14.7	5.1	2.3	15.2	—
Whitman							
stony loam	747						
Hinckley							
gravelly sandy loam	410	32.0	14.0	19.0	25.0	10.0	—
Merrimac							
fine sandy loam	1,512	43.6	13.3	8.4	7.8	26.9	—
Podunk							
loam	212	19.0	12.0	6.0	13.0	9.0	41.0
Meadow	1,334	14.0	21.0	24.0	9.0	—	32.0
Muck	1,357	—	—	12.0	26.0	—	62.0

New London County soil survey, but since it seemed desirable to obtain more detail than can be shown on the 1/62,500 map, and since conceptions of soil classification have developed materially during the last ten years, it was decided to make a new and more detailed soil survey on a scale of 1/31,250. Close correlation was maintained with the most recent soil types recognized by the Bureau of Soils survey in Massachusetts.

The writer was accompanied in the field by a forester, who prepared a land-cover map on the same scale as that used for the soil map, and collected data in regard to forest and pasture associations on the different soil types. The cover map showed areas of the following: (1) tilled land or mowing; (2) pasture nearly free from weedy or brushy growth; (3) pasture with considerable, though less than 50 percent, inedible forage; (4) pasture with over 50 percent inedible forage; (5) woodland, largely common mixed hardwoods; (6) swamp hardwoods.

During the same period, agricultural economists were obtaining very complete data from each farmer in the town. The results of the economic soil-type correlation studies will be presented in a subsequent paper.

The land-cover map was superimposed upon the soil map, so that planimeter measurements could be made of the culture on the various types of soil.

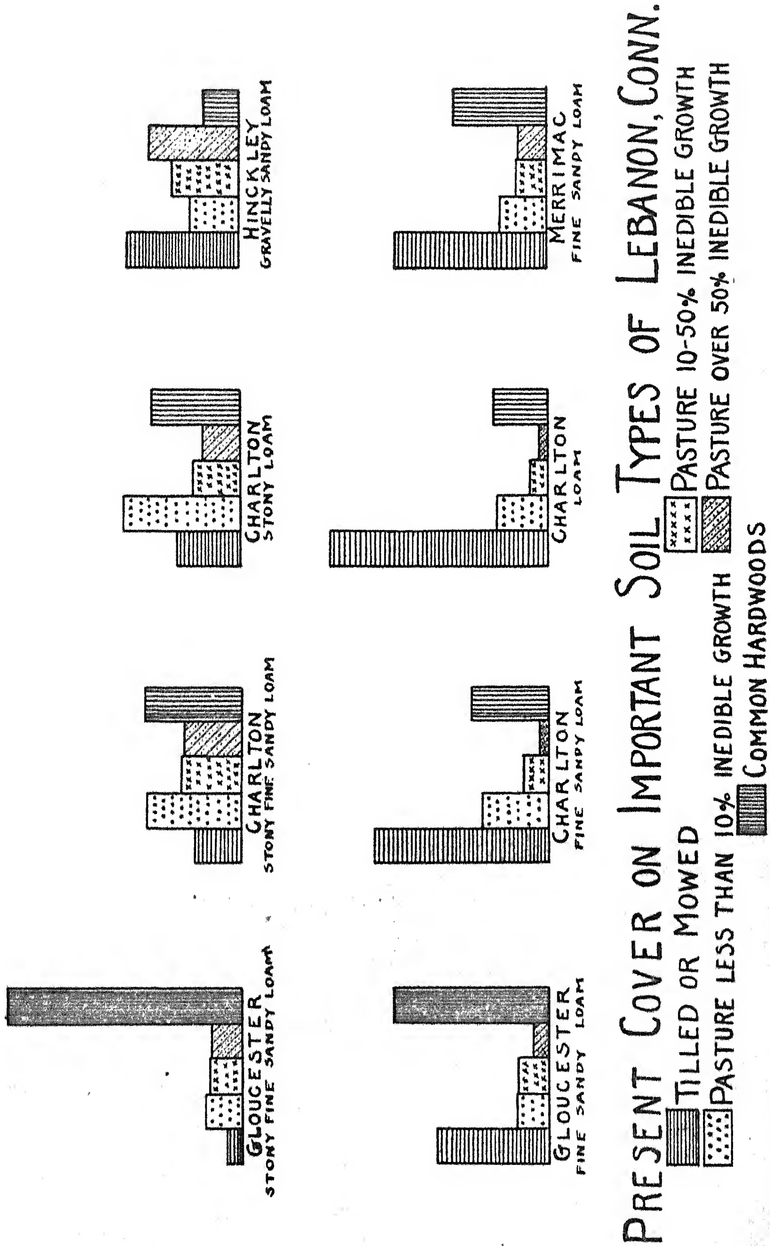
Data Obtained

The soil survey of 1923 mapped thirty-two soil types, as compared with only six recognized on the same area by the Bureau of Soils survey of 1911. Table 1 shows the basis of classification for the fifteen soil types which occur over a sufficient area to merit consideration in a correlation study of this sort. The land-cover distribution on the above types is given in Table 2; while figure 1 shows this graphically for the eight soils of most importance in this area.

DISCUSSION OF RESULTS

Of the three stony soil types the data for which are shown in Figure 1, the Gloucester stony fine sandy loam shows a particularly high percentage of woodland, an insignificant area of tilled land or mowing, and a relatively high ratio of the more inferior pasture grades.

The Charlton stony fine sandy loam has a smaller percentage in woodland, a much larger area of the better grade of pasture and has considerable tilled land or mowing in spite of the stony nature of the soil. The Charlton loam shows the same tendencies to a more marked degree.



PRESENT COVER ON IMPORTANT SOIL TYPES OF LEBANON, CONN.

Of the soils similar to the above except for their relative freedom from stone, the Gloucester fine sandy loam shows a moderate percentage of tilled land or mowing, with a high ratio of woodland even though neither stoniness nor topography are generally adverse to tillage. The present cover on the Charlton soils shows that two hundred years of experience has taught that these types are best adapted to tillage and improved pasture, and that the loam is the most desirable soil in the town for the dairy system of farming generally followed.

The uses now being made of the Hinckley gravelly sandy loam and the Merrimac fine sandy loam show that their low value as mixed hardwood sites is generally recognized, and that, in case of the former soil, its gravelly nature and excessive drainage have limited its use for tillage, and necessitated its utilization for inferior grades of pasture. The Merrimac soils show a more favorable condition for tillage, while the ratio of low quality pasture is much higher than with the Charlton soils.

Similar deductions can be drawn from a study of the data for the other soil types, although their limited occurrence, or abnormal relationships, limit the accuracy to a considerable degree.

CONCLUSIONS

It is believed that since a study of this sort shows certain well defined relationships of soil type to land cover, additional surveys in specially selected areas which show the best development of the important soil types, especially in the older agricultural regions of the east, may be expected to prove valuable contributions to a more accurate interpretation of the soil survey of similar areas of the same type of soil.

LITERATURE CITED

1. Brown, P. E. Soil types as a basis for soil investigations. *In* Jour. Amer. Soc. of Agron., 14:198–207. 1922.
2. Burlison, W. L. The utilization of the soil survey in crop experimental work, *In* Jour. Am. Soc. Agron. 16: 440-444. 1924.
3. Kelly, W. P. Plant indicators of soil types. *In* Soil Sci., 13:411–423, 1922.
4. Pendleton, R. L. Are soils mapped under a given name by the Bureau of Soils method closely similar to one another? *In* Univ. of Cal. Publ. in Agr. Sci., 3:369–498. 1919.
5. Sauer, C. V. A soil classification for Michigan. In 20th Report of Mich. Acad. of Sci.: 83–91. 1921.
6. Schoenmann, L. P. Description of field methods followed by the Michigan land and economic survey. *In* Rept. of 3rd. Ann. Meeting Amer. Assn. of Soil Survey Workers: 44–52. 1923.
7. Thorne, C. E. Fertilizing the wheat crop in Ohio. *In* Ohio Agr. Exp. Sta. Monthly Bul. 7:112–121. 1912.
8. Veatch, J. O. Soil in relation to forestry. *In* Mich. Agr. Exp. Sta. Quar. Bul. 6:67–68. 1923.

FACTORS WHICH INFLUENCE THE NICOTINE CONTENT OF TOBACCO GROWN FOR USE AS AN INSECTICIDE[1]

R. W. THATCHER, L. R. STREETER and R. C. COLLISON[2]

The high efficiency of nicotine as an insecticide for many types of insects which injure horticultural plants has aroused much interest in the possibility of securing more adequate supplies of this material at less cost than is possible at the present time. In South Africa, (1)[3] the government has established experimental mills for the production of tobacco extracts and has undertaken extension field experiments with the view of producing tobacco having a high nicotine content for use in the manufacture of these extracts; in the hope of not only supplying the home demand for this material but also of later establishing an extensive export trade in it. In the United States, the preparation of tobacco dusts and of nicotine extracts for insecticidal uses has thus far been chiefly a by-product industry. But the demands for these products is increasing rapidly and more efficient and economical sources of supply and methods of preparation are urgently needed.

In the past, the chief interest in the nicotine content of tobacco has naturally been in connection with its effect upon its smoking qualities. In 1909, Garner (2) discussed in detail the matter of the relation of the different forms of nicotine and of the organic acids which are formed in tobacco upon the so-called "strength" of tobacco when used for smoking purposes. Following this, most of the experimental work which has been done with tobacco has had in view the reduction of total nicotine, or of its change through fermentation in "curing" into forms which are less obnoxious to most smokers.

Recently, however, the discovery that the species of tobacco known as *Nicotiana rustica* generally contains much higher percentage of nicotine than do the varieties of *N. tabacum* which are commonly grown for smoking purposes, has suggested the possibility that this kind of tobacco might be grown especially for use as an insecticide either in the form of tobacco dust or as some nicotine preparation made from it. The entomologists, the insecticide chemists and the agronomist at the New York State Agricultural Experiment Station

[1]Contribution from the New York State Agricultural Experiment Station, Geneva, N. Y. Read by title at a meeting of the American Chemical Society held in Washington, D. C., April 23, 1924. Received for publication May 26, 1924.

[2]Director, Assistant in Research, (Chemistry), and Chief in Research (Agronomy), respectively.

[3]Reference by number is to "Literature Cited," p. 467.

all became interested in this possibility and a project involving field and laboratory studies of it was begun in the spring of 1922. These studies are by no means completed; but certain progress has been made and certain suggestions as to future possibilities have been developed which it seems desirable to report at the present time.

EXPERIMENTAL WORK

PRELIMINARY EXPERIMENTS WITH NICOTIANA RUSTICA

Our preliminary experiments, conducted in 1922, consisted essentially of a study of the nicotine content of plants of *Nicotiana rustica* when grown under different soil and cultural conditions at different localities in the vicinity of Geneva, New York.

A quantity of seed of this variety of tobacco was secured from the Office of Tobacco Investigation of the Bureau of Plant Industry of the United States Department of Agriculture. This seed was grown in Pennsylvania. It was planted in flats, at the experiment Station at Geneva, New York, and when the young tobacco plants were at the proper size for transplanting, several thousand of them were distributed to each of four fruit or vegetable growers, who operate farms at different localities in this vicinity upon quite widely varying types of soil. Instructions were given to these farmers to care for the crop as they would an ordinary crop of tobacco. When the plants were mature, samples were taken from each lot and brought to the experiment station laboratory, where they were dried and analyzed for nicotine content, with the results which are shown below in Table 1.

At the same time, other plants were set out in rows on the station grounds for an experiment to study the effects of topping versus non-topping and of various combinations of topping and suckering of the plants upon their nicotine content. In this plot, alternate rows of the plants were allowed to grow to maturity without removal of the seed-stalks; while on the intervening rows, blossom stalks were systematically removed as they appeared. Plants in certain rows were also suckered as well as topped. Different parts of these rows were topped and suckered at different intervals. At harvest time, samples of some of these plants were taken to the laboratory, dried, and analyzed for their nicotine content, with the results shown in Table 1.

Another experiment, to determine the effect of cultivation of transplanted tobacco grown in rows *versus* uncultivated broadcast field seeding, was carried out by seeding the tobacco broadcast directly on the soil of a small plot located not far from the rows of plants grown for the topping experiment mentioned in the preceding paragraph. These plants made a smaller and more spindling growth

Table 1. *Nicotine content of nicotiana rustica grown under varying soil and cultural conditions at Geneva, New York in 1922.*

Object of experiment and conditions	Nicotine in dry matter percent
A Influence of varying soil types.	
Tobacco grown at Junius, N. Y., on light sandy loam	0.59
" " " Phelps, N. Y. " medium clay loam	1.00
" " " Hall, N. Y. " " " "	0.97
" " " Hall, N. Y. " heavy bottom land	2.77
" " " Geneva, N. Y. " heavy clay loam	2.03
B Topping and suckering versus no treatment	
Plants grown to maturity without topping or suckering	2.03
Plants topped and suckered	2.40
C Growing in rows versus broadcast seeding	
Plants grown in cultivated rows	2.03
Plants grown from uncultivated broadcast seeding	1.51
D Nicotine content of different parts of plants	
Stems	0.80
Leaves	1.51

than did those grown in rows, but eventually headed out and matured seed. At harvest time, samples were taken, dried and analyzed, with the results shown in Table 1.

To study the nicotine content of the plants of this variety of tobacco at different stages of growth, samples were cut from one of the plots on July 21, when the plants were putting forth their first blossom clusters, and again on September 1, when the plants were matured and ready for harvesting in ordinary tobacco-growing practice. These samples were dried, and analyzed, with the results shown in Table 1.

Finally, to determine the distribution of the nicotine in different parts of the above-ground portions of the plants, certain of the sample plants which had been taken from plots as above described, after drying, were separated into different parts representing the stems, and the leafy portions, respectively. The separate portions were ground and analyzed for nicotine content, as shown in Table 1.

All of the tobacco grown on the station grounds during 1922 received an application of one ton per acre of a mixed fertilizer containing 240 lbs. each of nitrate of soda and dried blood, 320 lbs. of muriate of potash and 1,200 lbs. of acid phosphate.

All of the plants selected for analysis in the above described experiments were dried in an open attic, free from exposure to direct sunlight (which has been shown to cause losses in nicotine content (3)). When dry enough to permit grinding in an ordinary attrition mill, they were ground to a fine powder. Residual moisture in this ground material was determined by drying at room temperature in a vacuum oven P_2O_5 (attempts to dry the material at higher temperatures resulted in loss of nicotine in every case). The nicotine con-

tained in it was determined by the "official" silico-tungstic acid method as outlined by the Association of Official Agricultural Chemists (4).

The results of the first season's trials were disappointing in that all of the samples analyzed were much lower in nicotine content than had been expected from results elsewhere with this species of tobacco. However, the results did show marked variations in nicotine content due to variations in environmental conditions during the growth of the plants. Accordingly, it was planned to study in some more detail during the season of 1923, the influence of some of the factors which can be controlled by the grower, in order to throw some light upon the problem of how the highest possible nicotine content may be obtained.

VARIETY TESTS IN 1923

All of the tobacco grown in 1923 was fertilized in the same way as that grown in 1922, in order that the tests of the two seasons might be comparable with respect to this factor.

The results of our determinations of the nicotine content of *N. rustica* in 1922 having shown such unexpectedly low percentages of nicotine, it seemed desirable to determine, in 1923, whether this condition would apply also to several different varieties of *N. tabacum* if grown in this locality. Accordingly, seed of some thirty varieties of tobacco was secured from the experiment stations of Kentucky, Virginia, Connecticut, Pennsylvania and the United States Department of Agriculture. Young transplants from these seeds were set in adjacent rows in a plot on the experiment station grounds. At maturity, typical plants were selected from several of the varieties which had made sufficiently satisfactory growth to indicate at least approximate adaptibility to local conditions. These were dried and later the leaves analyzed for nicotine content, with the results shown in Table 2.

Table 2.—*Nicotine content of leaves of different varieties of tobacco grown at Geneva, New York, in 1923.*

Variety	Source of seed	Nicotine in dry matter per cent
N. *rustica*	Connecticut	3.99
" "	Pennsylvania	3.84
" "	Geneva, N. Y.	4.70
Yellow Pryor	Kentucky	1.50
White Burley	Kentucky	1.10
Yellow Pryor	Washington, D. C.	1.47
Penn. broadleaf	Washington, D. C.	1.14
Blue Pryor	Virginia	1.40
Big Oronoco	Virginia	1.38
Lizard tail Oronoco	Virginia	1.23
Big Havana	Virginia	1.37
Yellow Pryor	Virginia	1.53

These results indicate that under identical conditions, *N. rustica* develops approximately three times as high a nicotine content as do other common strains of *N. tabacum*. This is according with the findings of Juritz in South Africa (5) and Garner in this country (6). Further, it is to be noted that the sample of *N. rustica* which was grown from seed collected from plants which grew at this Station in 1922 was quite different in its habit of growth and the plants were much less uniform in appearance than were those of the other two strains of this species. This strain of *N. rustica* showed the highest nicotine content of any of the lots included in the test. It is not certain whether this is due to an inherent difference in unsegregated strains of this new species, or to the influence of one year of adaptation to the local environment in the case of this one strain. To clear up this possible uncertainty, it is planned to plant again, in 1924, several of those strains side by side, using new seed of similar out-of-the-state origin, and planting alongside this seed which has been collected from plants of the same variety grown here at Geneva in 1922 and 1923, wherever possible.

INFLUENCE OF ORIGIN OF SEED ON NICOTINE CONTENT

Included among the thirty samples of seeds for the variety tests mentioned above were five lots of the Pryor variety, but collected from plants grown in different states and hence of quite widely different origin. The results of the analysis of the leaves of the plants grown from these five lots of seed are shown in Table 3.

Table 3.—*Nicotine content of Pryor tobacco grown from seed of different origin.*

Source of Seed	Nicotine in dry matter per cent
Yellow Pryor from Kentucky (dark type)	1.50
Yellow Pryor for Virginia	1.53
Yellow Pryor from Washington, D. C.	1.47
Kentucky Pryor grown in Virginia	1.64
Blue Pryor from Virginia	1.40

These somewhat meager results, considered along with others reported in later paragraphs would seem to us to indicate that the local environmental factors during growth are likely to be a more potent influence in determining the nicotine content of any given variety of *N. tabacum* than is the source of origin of the seed from which it is grown.

PLANTS GROWN IN CULTIVATED ROWS VERSUS BROADCAST SEEDING

This experiment was repeated in 1923, using three different strains of *N. rustica*, with the results shown in Table 4.

Table 4.—*Effect of method of culture on nicotine content of N. rustica grown at Geneva, New York, in 1923*

Strains of tobacco	Nicotine in dry matter Cultivated rows per cent	Nicotine in dry matter Broadcast seeding per cent
N. rustica, No. 5	3.99	2.95
" " No. 34	4.70	2.09
" " No. 35	3.84	2.58

These results, which are in agreement with those obtained in 1922, would seem to indicate that the sowing of the crop broadcast without summer cultivation, while it might be the more economical method of growing the crop for use as an insecticide, affects the nicotine content of the tobacco so unfavorable as to render it an inadvisable practice. It may be, however, that heavy fertilization with available nitrogen would tend to overcome this difficulty and so make it possible to use this more economical method of growing the crop. This point will receive further experimental study. In addition the effect of the broadcasting versus cultivated row system of cultivation upon the proportion of leafy parts to stems of the plants needs to be studied, since this is an important factor in the tonnage per acre of material available for insecticide use.

EFFECT OF FERTILIZERS UPON NICOTINE CONTENT OF *N. Rustica*

The results obtained by Ames and Boltz at the Ohio Experiment Station (7) with *N. tabacum*, and our experience in 1922 with *N. rustica* seem to show clearly that the nicotine content of tobacco is largely influenced by the quantity and kind of available plant food material in the soil on which it grows. Apparently, available nitrogen is especially favorable to the development of high nicotine content. We had planned, therefore, to conduct a considerable series of experiments in fertilization of *N. rustica* with materials carrying available nitrogen in 1923. Unfortunately, however, it was impossible to get these under way.

But it happened that in another department of the Station a series of plots which were being given very unusual and heavy applications of certain pure chemicals, in a quite different study, was this year planted to tobacco of the *N. rustica* variety, using seed of the strain No. 34, which was grown at Geneva in 1922. It happened also that one-half of each of the thirteen plots in this series was set to the tobacco plants early in the season (June 24) and the plants grew rapidly during the hot summer months to full maturity by August 24; while the other half of the same plots were not set until July 20 and the plants grew much more slowly during the cooler late summer months, so that they were not quite fully mature when it was neces-

sary to harvest them before they would suffer injury by frost (October 4). Each alternate plot of the series (Nos. 1. 3. 5. 13) was an untreated check, so that the crops grown on these plots gave an opportunity to study both the effect of the added chemicals and that of the varying seasonal conditions under which the plants grew, upon the nicotine content of the tobacco. Accordingly, samples of the tobacco from each cutting from each plot were dried and analyzed to determine total yield of dry matter per plot and nicotine content.

The treated plots have been given the following applications each year of the chemicals which were being used in the experiment.

No. 2. Sodium sulfate 1000 lbs. per acre 1890–1922; 1600 lbs. per acre in 1923.

No. 4. Magnesium sulfate 1000 lbs. per acre 1890–1914; 2000 lbs. per acre 1915–1923.

No. 6. Calcium sulfate 2000 lbs. per acre 1890–1923;

No. 8 Ferrous sulfate 100 lbs. per acre 1890–1911; 500 lbs. per acre 1912–1914; 1000 lbs. per acre 1915–1923.

No. 10. Sodium chloride 500 lbs. per acre 1890–1923.

No. 12. Calcium carbonate 2000 lbs. per acre 1890–1923.

The results of the soil treatments and of the seasonal conditions upon the nicotine content of the tobacco from the two different crops are shown in Table 5.

Table 5.—*Effects of varying soil treatments and seasonal conditions on the nicotine content of N. rustica grown at Geneva, New York, in 1923*

Plot No.	Chemical applied	pH of the soil	Nicotine in dry matter Early crop per cent	Late crop per cent
1	None	6.1	7.26	3.13
2	Sodium sulfate	6.2	4.90	2.65
3	None	6.2	5.80	4.12
4	Magnesium sulfate	6.2	5.66	3.30
5	None	6.1	5.76	3.29
6	Calcium sulfate	6.2	5.50	2.93
7	None	6.2	6.10	3.07
8	Ferrous sulfate	5.6	5.61	4.26
9	None	6.2	4.84	3.42
10	Sodium chloride	6.2	4.51	2.44
11	None	6.2	4.40	3.48
12	Calcium carbonate	7.8	5.41	3.28
13	None	6.2	4.36	2.54

These results clearly show a very marked effect upon the nicotine content of the tobacco of the seasonal conditions during growth or the influence of these conditions upon the maturity of the plants at the time when the crop is harvested. Warm weather, favoring rapid growth and early maturity, very evidently produced increased percentages of nicotine in the tobacco. There is also an indication of some

effect of the varying soil treatments upon the nicotine content of the tobacco, but this is slight in comparison with the seasonal, or climatic, influence. However, these soil treatments were not planned to affect the supply of available nitrogen supply, except perhaps indirectly through their effect upon its alkalinity or acidity (as indicated by the pH of the soil). Since the available nitrogen content of the soil is probably the most potent factor, so far as plant food supply is concerned, in influencing the nicotine content of tobacco, these experiments will need to be supplemented with others in which various nitrogen-carrying fertilizers are used before final conclusions as to the possibility of increasing the nicotine content of tobacco grown for use as an insecticide can be drawn.

SUMMARY

The growing of tobacco with a high nicotine content for use as an insecticide is an interesting and promising possibility.

Former investigations of the factors which influence the nicotine content of tobacco and attempts to control these so as to change the character of the crop have always had the end in view of reducing the nicotine content or of ameliorating its character so as to improve the smoking quality of the leaf.

The investigations reported in this paper, together with similar results by other workers from studies undertaken with the opposite purpose in view, clearly indicate that the nicotine content of any particular variety or crop of tobacco is very largely influenced by the plant food supply and climatic conditions under which it is grown.

There is also the possibility of selection of high-nicotine content plants as parent stocks for tobacco to be grown for insecticide use, particularly from a strain of *N. rustica* which shows great variation between individual plants.

These facts seem to offer an excellent opportunity for experimental efforts to increase the nicotine content of tobacco grown for use as an insecticide.

LITERATURE CITED

1. PIETER KOCH. "Nicotiana rustica" as a possible source of tobacco extract. *In* Jour. Dept. Agr. Union So. Africa, 7: 416–419 (November, 1923).
2. GARNER, W. W. The relation of nicotine to the burning quality of tobacco. *In* U. S. Dept. Agr., Bur. Plant Ind. Bul. 141. pp 1–16, 1909.
3. J. duP. OOSTHUIZEN. Tobacco cultivation for nicotine. *In* Jour. Dept. Agr. Union So. Africa. 6:166–175 (February, 1923).
4. Official Methods of Analysis (Revised) (November, 1919).
5. JURITZ, CHAS F. The nicotine content of South African tobacco. *In* Jour. Dept. Agr. Union So. Africa 4:552–562 (June, 1922).
6. GARNER, W. W. Unpublished data.
7. AMES, J. W., and BOLTZ, G. E. Tobacco. Influence of fertilizers on composition and quality. Ohio Agr. Expt. Sta. Bul. 285. 1915.

A METHOD OF DETECTING MIXTURES IN KANRED WHEAT SEED[1]

C. O. JOHNSTON and C. W. BOWER[2]

Widespread popularity and a large demand for seed of any particular variety of wheat often lead to mixtures, intentional and otherwise, which may injure the reputation of that variety. A common method of preventing the widespread sale of such mixtures has been the field inspection and certification of seed by crop-improvement associations and other agencies. The effectiveness of these methods often is impaired, however, by varietal similarities so great as to render it extremely difficult for even trained inspectors to detect mixtures in the field. Consequently, an accurate method by which mixtures in the threshed grain can be detected is very desirable.

Kanred wheat, a variety widely grown in the hard-red-winter-wheat belt, and very similar in morphological characters to other varieties of the same area, is a case in point. For a number of years, the Kansas Crop Improvement Association has inspected and certified fields of Kanred wheat. Under normal conditions this variety can be distinguished from other varieties of hard red winter wheat with a fair degree of accuracy by the greater length of the beaks on its outer glumes. When affected by drought or other abnormal growth conditions, however, this difference may not be marked, and it becomes very difficult if not impossible to distinguish Kanred from other related varieties by this method. To overcome this difficulty, effective use has been made of the differential reaction of Kanred and the other varieties of hard red winter wheat to certain specialized races or strains of stem rust, *Puccinia graminis tritici* Erikss. and Henn.

It has been known for some time that Kanred is immune from certain strains of stem rust to which other varieties of hard winter wheat grown in Kansas are susceptible (1, 2).[3] A strain of stem rust from which Kanred was known to be immune was used in the separation studies herein described. This culture was increased in a

[1]Joint contribution from the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture, and the Departments of Agronomy and of Botany and Plant Pathology ,Kansas State Agricultural College. Contribution No. 227 from the Department of Botany and Plant Pathology and Contribution No. 153 from the Department of Agronomy. Received for publication May 6, 1924.

[2]Assistant Pathologist, Office of Cereal Investigations, United States Department of Agriculture, and Student Assistant, Department of Agronomy, Kansas State Agricultural College, respectively.

[3]Reference by number is to "Literature Cited," p. 470.

greenhouse free from other rust cultures until a large supply of urediniospore material was available.

It readily can be seen that if seedlings grown from mixed seed are subjected to inoculations with a strain of stem rust from which Kanred is known to be immune, the seedlings which become rusted are not pure Kanred. This can be said with certainty as none of the other hard winter wheats grown in Kansas is immune from the strain of rust used. By the simple process of counting the rusted and rust-free seedlings the percentage of mixture in the sample can be determined.

To make this test, seed collected by the inspectors and samples sent in by the growers were used. The kernels were sown in 2½-inch flower pots, which are easy to handle and allow sufficient growth of the seedlings. Twelve to fourteen kernels were sown in each pot and ten pots sown from each sample of seed, the plan being to obtain about one hundred seedlings for the rust experiment. At the same time several pots of recently pedigreed Kanred seed, known to be practically free from mixture, and of Improved Turkey, an extremely susceptible variety, also known to be free from mixture, were sown as checks. Care was taken to see that several pots of these two varieties were tested in each series of seedlings from the seed sent in by growers.

The seedlings were inoculated after about two weeks' growth, or when the second or third leaf was well out. Two methods have been used in inoculation. In 1922 the method described by Melchers and Parker (3), in which only the first seedling leaf was inoculated, was used. As this required a great deal of time, a method whereby the seedlings were allowed to grow to about the third-leaf stage before they were inoculated, was employed in 1923. In this method the leaves were thoroughly moistened with an atomizer and then subjected to inoculation by vigorously shaking heavily rusted seedlings above a group of pots. This causes a shower of urediniospores to fall on the moist leaves of the seedlings. As such a large leaf area is exposed for inoculation, there is practically no possibility of any plant being missed. This method proved to be rapid and effective. After inoculation all pots of seedlings were placed in moist chambers for 48 hours, and then removed to the greenhouse bench. Sporulation resulted in most cases in from eight to ten days. Final notes were taken on all seedlings at the end of fourteen days.

When conditions in the moist chambers were favorable for infection, very marked differences were obtained in the amount of rust on the seedlings in various samples and in the two check varieties.

With very few exceptions the Kanred checks were entirely free from rust, the Improved Turkey checks had one hundred per cent of the plants rusted, and the growers' samples showed from zero to fifty per cent of the plants rusted. Where there was any doubt about the results obtained from any inoculation, the experiment was repeated.

The results obtained in 1922 and again in 1923 were very satisfactory and the data proved a valuable aid to the certification of the seed. As a general rule the mixed samples contained some heavily rusted plants and others which were entirely free from infection, without intermediate grades. This fact, coupled with the complete susceptibility of Improved Turkey and immunity of simultaneously inoculated Kanred checks, left little doubt as to the significance of the results. To emphasize this point, data taken from the 1923 records are given in Table 1.

These data are typical of the records obtained during both years. When it is realized that nearly two hundred growers sent in samples to be tested each year, some idea of the scope of the work can be obtained. In 1923 about 12,000 seedlings were used in carrying out these tests.

There were a few cases in the experiments of each season in which the Kanred checks were not entirely free from rust and in which

TABLE 1.—*Results obtained from inoculation of seedlings from 12 different lots of seed of Kanred and from immune and susceptible checks, with spores of a single known strain of stem rust of wheat.*

Lots tested		Address of grower	Seedlings grown	Seedlings rusted Number	Seedlings rusted Percentage
Sample No.	51	Sabetha, Kansas	111	6	5.4
"	52	Russell, Kansas	110	26	23.6
"	53	Blakeman, Kansas	128	13	10.2
"	54	Coats, Kansas	117	6	5.1
"	55	Coats, Kansas	104	4	3.9
"	56	Kingston, Kansas	127	6	4.7
"	57	Hardy, Nebraska	125	2	1.6
"	58	Coldwater, Kansas	128	19	14.8
"	59	Coldwater, Kansas	117	18	15.4
"	60	Richmond, Kansas	114	9	7.9
Susceptible Check. Improved Turkey, (Kan. No. 2382)		K. S. A. C., Manhattan, Kansas	105	105	100.0
Resistant Check. Kanred (Kan. No. 2401)		K. S. A. C., Manhattan, Kansas	57	0	0.0

Improved Turkey did not show one hundred per cent of the plants infected, but these were exceedingly rare. For example, in 1923, only 9 of the 638 Kanred check plants showed any infection. When rust from some of these infected seedlings was transferred to other Kanred seedlings, no infection resulted, indicating that they were chance mixtures in the Kanred seed used as checks. Only 5 out of a total of 933 inoculated seedlings of Improved Turkey failed to become infected.

The results obtained in these experiments show that the rust test applied to seedlings is a good index of the purity of Kanred seed wheat. It is a rapid and accurate method and should prove a valuable supplement to field inspection. The method is not applicable to Kanred alone, but with the proper specialized forms of stem rust could be used for Marquis, Kota, and several of the durum wheats. The leaf rust of wheat may be used for similar tests to detect mixtures in certain strains of Mediterranean, Fulcaster, and other varieties of soft red winter wheat. The method seems especially adapted to the needs of Seed Growers and Crop Improvement Associations, and might also be used by seed houses and millers.

LITERATURE CITED

1. MELCHERS, LEO E. and PARKER, JOHN H. Three varieties of hard red winter wheat resistant to stem rust. Abs. *in* Phytopath. 8:79. 1918.
2. STAKMAN, E. C. and LEVINE, M. N. The determination of biologic forms of Puccinia graminis on Triticum spp. Minn. Agr. Exp. Sta. Tech. Bul. 8. 1922.
3. MELCHERS, LEO E. and PARKER, JOHN H. Rust resistance in winter wheat varieties. U. S. Dept. Agr. Bul. 1046. 1922.

BOOK REVIEW

THE PRODUCTION OF FIELD CROPS

By T. B. Hutcheson and T. K. Wolfe. McGraw-Hill Agricultural and Biological Publications, edited by C. V. Piper. McGraw-Hill Book Co., Inc., New York. Rp. XV + 499. Fig. 145. 1923. $3.50.

The appearance of "The Production of Field Crops," by Hutcheson and Wolfe, is a new "mile-stone on the way of progress" in the development of field crop textbooks. As the first book to closely conform to the outline for standard introductory field crop courses, recently adopted by the American Society of Agronomy, this book should fulfill the present needs of a large majority of the agricultural colleges of the United States.

The material is handled in a thorough, well organized manner. The review of agronomic experiments of the experiment stations and of the United States Department of Agriculture is up-to-date and more complete than any previously presented. While Virginia experiments are dealt with in considerable detail, the work referred to is largely the work of the writers of the book and brings out points as well as similar detailed reports of results from other stations. The careful treatment of the experimental results from numerous other stations offsets any criticism which may be made to the effect that this book stresses Virginia work and conditions. Greater attention is given to varietal adaptation, according to states and sections, than in any crops book that has as yet been issued. This book can well be accepted as a standard text even in the extreme northern tier of states, by supplementing some additional material in regard to such crops as sugar beets, beans, spring wheat, etc.

It is the opinion of the reviewer that Hutcheson and Wolfe's, "The Production of Field Crops," will render a great service in the agronomic field. (J. F. Cox.)

AGRONOMIC AFFAIRS

NOTES AND NEWS

Frederick D. Richey, Agronomist in charge of corn investigations in the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture, and Professor R. A. Emerson, Head of the Department of Plant Breeding of Cornell University, returned recently from a four months trip to South America, in search of varieties of corn that will grow at low temperature, or possess notable resistance to disease or insect attacks, to be used in genetic studies and in breeding for improvement in these characters. Something over two hundred samples were secured. These were collected in Argentine, Chili, Peru and Bolivia. Some of them were secured from localities where corn is grown at elevations of 7,000 to 12,500 feet above sea-level, others where the temperature is

practically uniform during the growing season at not much above 50° F. for the day and 40° F. at night. The samples obtained will afford excellent material for both genetic and adaptation studies.

C. H. Bailey, Associate Agricultural Biochemist in charge of the Section of Cereal Technology of the Division of Agricultural Biochemistry at the University of Minnesota and also in charge of the state experimental flour mill in Minneapolis has been granted a year's leave of absence to become technical director of the Biscuit and Cracker Manufacturers' Association at Chicago, Ill. Dr. Bailey will continue to perform his duties as editor of "Cereal Chemistry" during his leave.

J. D. Romaine, formerly assistant instructor in soils at the Pennsylvania State College, has accepted a position as assistant in soils at the Michigan Agricultural College.

The annual conference of Eastern Agronomy Extension Specialists was held at the State College of Pennsylvania on June 16 and 17. Representatives were present from the states of New York, New Jersey, Delaware, West Virginia, Pennsylvania and Ohio and from the United States Department of Agriculture. A very pleasant and profitable meeting is reported.

TO STUDY PLANT LIFE IN EASTERN AFRICA

Dr. H. L. Shantz, of the Bureau of Plant Industry of the U. S. Department of Agriculture, has joined the educational commission which is now on its way to Abyssinia and will study the native fruits, flowers, trees, vegetables and grains of Eastern Africa with the view to their possible adaptation to American agriculture.

The route of the expedition will include the countries along the eastern coast of Africa, beginning at Abyssinia, thence through Konya, the Uganda Protectorate, Nairobi, Tanganyika Territory, Nyasaland, Northern and Southern Rhodesia, Portugese East Africa, and South Africa.

While the other members of the commission will be chiefly interested in studying the educational needs of the people in these different countries in the light of their religious, social, hygienic and economic conditions, Dr. Shantz will concern himself chiefly with the flora of the regions visited. He will also study the native methods of planting and harvesting crops, and it is expected that many new plants and seeds will be secured for trial and ultimate adaptation in America. Dr. Shantz plans to be away on the trip for approximately a year and a half.

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SOME FACTORS AFFECTING THE WATER ABSORPTION AND GERMINATION OF SEED CORN[1]

George H. Dungan[2]

INTRODUCTION

The first step in the germination of corn is the intake of moisture. The purpose of this paper is to present the results of a series of experiments dealing with the water absorption and germination of seed corn as these processes are influenced by (a) the stage at which the corn is harvested, and (b) the chemical and physical composition of the corn kernel.

THE INFLUENCE OF STAGE OF HARVESTING ON WATER ABSORPTION

Seed corn of the Reid's Yellow Dent variety was harvested at three different dates. When gathered, the content of the kernels of the first lot was milk-like in consistency. This period in the development of cereals is commonly referred to as the "milk-stage." The endosperm of the kernels of the second lot possessed the character of dough, and the crown of the grains was well dented. The third sample, when harvested for seed, was completely mature and was dry enough for husking. These three lots of corn were stored under the same conditions, and when cured, they all contained practically the same amount of moisture. Just before water absorption determinations were made, the "milk-stage" corn contained 9.5 percent of water; the "dent-stage," 10.7 percent; and the "mature-stage," 10.3 percent.

The imbibition experiments consisted in a determination of the quantity of water that the corn absorbed in a twenty-four hour

[1]Contribution from the Agronomy Department, University of Illinois, Urbana, Illinois. Received for publication, May 14, 1924.

[2]Associate in Crop Production.

period. The corn was allowed to soak in distilled water at six constant temperatures,[3] ranging, with five degree intervals, from 5° to 30° centigrade. At the end of the twenty-four hour soaking period, the water was poured off the corn and the moisture on the surface of the kernels was rubbed off with a towel. The swollen kernels were then weighed. The amount of water imbibed by the corn was obtained by difference—subtracting the weight of the corn before soaking from that of the same kernels fter soaking. The calculations of percentage absorption were made on the basis of water-free corn. Thus, the data presented in Table I represent the percentage of water absorbed during the period of soaking plus the water already present in the air-dry corn.

TABLE I.—*Average percentage water imbibed by corn harvested at three differen stages of maturity during a period of twenty-four hours soaking in water maintained at six different temperatures.*

Temperature	"Milk-stage" corn	"Dent-stage" corn	"Mature-stage" corn
5°C.	74.13%	64.06%	46.28%
10 "	85.16 "	68.71 "	53.97 "
15 "	89.91 "	70.03 "	57.98 "
20 "	90.08 "	71.78 "	59.26 "
25 "	94.39 "	72.90 "	60.93 "
30 "	91.47 "	72.57 "	61.07 "
Average	87.52 "	70.01 "	56.59 "

It is quite evident from these data that the corn harvested in an immature condition absorbed water more rapidly than did that gathered after complete maturity. Although chemical determinations were not made, it was easy to observe that there was progressively a smaller proportion of soft starch in the kernels as the corn matured. The greater absorption of the starchy kernels in this experiment is in accordance with the results of Coffman (3)[4] who, in his germination of seeds at low temperature, noted that starchy seeds absorbed more water than did less starchy seeds of the same species.

The imbibition of water is commonly considered a prerequisite to germination, but not a part of this process. Atkins (1), working with beans, found that there is no difference in absorption between living and dead seeds until after germination, when the protoplasmic membrane is formed.

Temperature plays an important part in the rate at which water is imbibed. Up to 25° centigrade there is an increase in the amount of water taken up for each five degrees increase in temperature. This

[3]These investigations were made in the control temperature chambers devised by Dr. Chas. F. Hottes, Plant Physiology Laboratory, University of Illinois.
[4]Reference by number is to "Literature Cited," p. 481.

increase, however, is not consistently uniform. The quantity of water imbibed at 30° was less for "milk-stage" corn and "dent-stage" corn than it was at 25°. The velocity with which water is absorbed by corn is, therefore, seemingly not wholly an exponential function of the temperature, as was pointed out by Brown and Worley (2) in their work with barley seeds. Shull (7) states that it is his conviction after a number of years of experience with absorption phenomena, that absorption is a complex process dependent upon a number of factors, some of which may be external, but many of which are internal. His work with Xanthium seeds and split peas indicates that absorption is both a chemical and a physical process that is not entirely dependent upon temperature.

RELATION OF THE OIL AND PROTEIN CONTENT OF CORN TO RATE OF WATER ABSORPTION

Imbibition determinations were made on corn from four ears each of the Illinois High Oil, Illinois Low Oil, Illinois High Protein and Illinois Low Protein strains (8) supplied by the Plant Breeding Division of the Illinois Agricultural Experiment Station. The average percentage of oil in the first two types mentioned was 9.40 for the high oil and 1.82 for the low oil. The high protein strain contained 15.29 percent protein, while the low protein strain contained only 6.10 percent. In other words, the high oil corn contained 5.16 times as much oil as the low oil corn, and the high protein corn contained 2.18 times as much protein as the low protein strain. The percentages of water imbibed by these different types of corn are shown in Table 2.

TABLE 2.—*Average percentage water absorption by high and low oil corn and high and low protein corn during a twenty-four hour period at six different temperatures.*

Strain	Percent water in air dry corn	Percent water imbibed at 5°	10°	15°	20°	25°	30°	Average
High oil	7.44	35.95	39.27	45.19	44.55	50.35	52.92	45.37
Low oil	8.88	34.58	38.18	43.78	47.84	49.29	50.03	43.95
High protein	6.75	29.17	31.90	37.47	42.78	45.01	46.76	38.85
Low protein	7.63	36.04	39.51	44.89	48.80	51.94	55.41	49.10
Average	7.68	33.94	37.22	42.83	45.99	49.15	51.28	

From these data, it appears that there is little difference in the rate of absorption by high and low oil corn. The germ of the high oil kernels is much larger than that of normal corn, whereas the endosperm of the low oil corn is unusually large in proportion to the germ. It appears, then, that the imbibitional ability of the oily germ is practically the same as that of the large, relatively starchy endosperm.

The difference between the percentage of water taken up by the high and low protein strains is very great. A large part of the protein of the high protein strain is contained in the endosperm. This gives the endosperm a hard vitreous texture. It would seem, then, that this horny character of the kernel contributes to the low absorptive rate of the high protein corn.

WATER ABSORPTION IN RELATION TO THE DISEASED CONDITION OF CORN

The influence of the horny character of the endosperm on water absorption was further emphasized in imbibition studies with some diseased and nearly disease-free corn furnished by a representative of the United States Department of Agriculture. The diseased corn was classed as such because of its susceptibility to the scutellum rot (6) disease. A very large proportion of the corn that is susceptible to scutellum rot contains a high soft starch content. On the other hand, a high percentage of the nearly disease-free corn is horny in texture and contains comparatively little soft starch (6). The results of these studies are shown in Table 3.

TABLE 3.—*Average percentage of water absorbed by nearly disease-free corn and corn susceptible to the scutellum rot disease during a twenty-four hour period at five different temperatures.*

Variety	Type	Percent water in air-dry corn	Percent water imbibed at 10°	15°	20°	25°	30°	Average
Funk's Yellow Dent	Nearly disease free	9.00	38.37	42.20	46.89	48.12	48.97	44.91
	Susceptible to scutellum rot	9.20	41.35	49.59	50.64	52.96	57.70	50.45
Reid's Yellow Dent	Nearly disease free	10.80	40.94	46.58	48.17	50.01	50.83	47.31
	Susceptible to scutellum rot	9.50	42.00	49.32	52.10	53.85	57.79	51.01
Average		9.63	40.67	46.95	49.45	51.24	53.82	

Here, again, as in the preceding studies, the corn higher in proportion of soft starch imbibed the greater percentage of water. This property of rapid water absorption on the part of starchy corn may be a factor which contributes to its susceptibility to scutellum rot.

INFLUENCE OF STAGE OF HARVESTING SEED CORN ON GERMINATION

The germination tests were made on plaster of paris blocks, two inches thick and eight inches square. These were placed in galvanized-iron pans and water poured into the pans until it came within one-eighth inch of the top of the blocks. The corn kernels to be tested for germination were laid, germs up, on these blocks. A

metal cover was placed over each pan to maintain suitable humidity for germination. By this method it was possible to observe every step in the development of the seedlings. Duplicate sets of fifty grains each were tested in the temperature chambers maintained at 15°, 20°, 25°, and 30°, respectively. Observations were made daily and records were taken of the number of radicles and plumules that appeared. These data are shown in Table 4.

TABLE 4.—*The germination record of corn harvested at three different dates and tested for germination at four different temperatures.*

Temperature	Stage harvested	Average percentage germination in 2 days r[a]	2 days rp[a]	3 days r	3 days rp	4 days r	4 days rp	5 days r	5 days rp	6 days r	6 days rp	Vitality (producing either a radicle or plumule) %	Germination (producing both a radicle and a plumule) %
15°C.	Milk	0	0	0	0	0	0	0	0	0	0	0	0
	Dent	0	0	3	0	7	0	7	0	7	0	7	0
	Mature	0	0	0	0	0	0	0	0	0	0	0	0
20°C.	Milk	9	0	23	1	69	11	43	37	29	63	92	63
	Dent	10	1	17	3	34	34	30	49	17	75	92	75
	Mature	1	1	10	12	36	26	22	46	11	83	94	83
25°C.	Milk	17	0	35	4	48	32	24	62	22	66	88	66
	Dent	23	1	33	7	28	62	18	78	9	88	97	88
	Mature	3	1	27	3	35	58	4	91	4	93	97	93
30°C.	Milk	36	7	39	25	24	66	—	—	—	—	90	66
	Dent	29	9	30	32	20	73	—	—	—	—	93	73
	Mature	27	0	36	20	15	81	—	—	—	—	96	81

[a]The numbers in the columns headed "r" represent the percentage of kernels that possessed a radicle only on the day the observation was made; the figures under "rp" show the percentage of kernels that had completely germinated; that is, had produced both a radicle and a plumule.

The corn harvested in the "milk-stage" began germinating earlier than that harvested in the "dent-stage." The latter, likewise, produced a higher percentage germination during the first three days than the corn gathered after it had become mature. Soon, however, the "milk-stage" seed showed evidence of lack of vigor, as may be noted from the "rp" results at the end of the fourth day. The superiority of the "mature-stage" corn is strikingly brought out in the column giving the percentage of complete germination. The corn in the 30° chamber, particularly that harvested at the "milk-stage," was soon overrun by molds (*Rhizopus* sp., *Penicillium* sp., and *Aspergillus* sp.) and for that reason the germ emergence was abnormal. The test at this temperature was discontinued at the end of the fourth day.

It seems from these results that although early harvested seed corn absorbs water more rapidly than corn that is allowed to mature on the stalk, the mature corn is distinctly the better from the standpoint of seedling vigor. Goff (7) has conducted field experiments on

the effect of continued use of immature seed corn. He used King Philip, a flint corn, making seed selections at five different stages of maturity. The average yields obtained by Goff covering a period of three years (1896–1898) on plots 10 hills wide and 50 feet long are as follows:

First selection	(most immature)	282.2	pounds
Second	"	309.0	"
Third	"	323.9	"
Fourth	"	322.6	"
Fifth	" (fully mature)	328.3	"

These results also emphasize the importance of allowing seed corn to mature on the stalk. This practice is not always advisable, however, in view of the difficulty of obtaining seed from healthy plants, and of harvesting seed corn before it is injured by freezing. In view of the advantage of late harvested seed, if it were evident that the corn was going to mature before danger from freezing weather, it might be advisable to select the seed corn in the field while the stalks were still green, but not to remove the ears from the stalks. The husks of such ears could be marked in some convenient manner, as for instance, applying a splash of colored paint, and the ears then left on the stalks until completely mature.

INFLUENCE OF AMOUNT OF MOISTURE IN SEED CORN DURING STORAGE UPON GERMINATION

The moisture in seeds is a very important factor influencing the life processes going on within them. At a given temperature a decrease in moisture content reduces respiration. On the other hand, as the quantity of water present in the seed increases, respiration also increases. This increase probably continues up to the point where the quantity of moisture limits the oxygen supply.

In order to study the influence on germination of moisture in corn during storage, some corn was selected from the crib in the spring. An attempt was made to obtain samples of corn containing widely different percentages of water. One lot (lot 3) was found which showed a water content of 19.2 percent. The driest composite lot of corn (lot 2) found in this crib contained 12.6 percent of water. These two lots of corn were germinated on plaster of paris blocks along with a third sample (lot 1) of the same kind of corn that had been stored in the laboratory during the winter. The latter sample had a moisture content of 6.1 percent. The results are shown in Table 5.

It will be noted that the corn containing the largest amount of initial water produced the greatest percentage of radicles in two days

TABLE 5.—*Germination tests of corn containing different amounts of moisture.*

Temperature	Lot	Moisture in corn %	2 days r[a]	2 days rp[a]	3 days r	3 days rp	4 days r	4 days rp	5 days r	5 days rp	6 days r	6 days rp	7 days r	7 days rp	8 days r	8 days rp	18 days r	18 days rp	Vitality %
10°C.	1	6.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	12.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	3	19.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	3	10
20°C.	1	6.1	0	0	0	0	0	0	0	0	7	0	28	3	45	7	1	95	96
	2	12.6	0	0	0	0	0	0	0	1	46	4	66	14	59	30	2	97	99
	3	19.2	0	0	0	0	2	0	12	1	33	3	30	9	27	18	3	77	80
25°C.	1	6.1	3	0	17	0	55	32	—	—	—	—	—	—	—	—	—	—	87
	2	12.6	44	0	73	12	20	80	—	—	—	—	—	—	—	—	—	—	100
	3	19.2	55	0	61	19	14	72	—	—	—	—	—	—	—	—	—	—	86
30°C.	1	6.1	91	0	29	63	—	—	—	—	—	—	—	—	—	—	—	—	92
	2	12.6	97	0	9	88	—	—	—	—	—	—	—	—	—	—	—	—	97
	3	19.2	85	0	12	73	—	—	—	—	—	—	—	—	—	—	—	—	85

[a]"r" = percentage of kernels that possessed radicles; "rp" = percentage of kernels that possessed both radicles and plumules.

at 25° centigrade. At the end of the third day, the dry corn had not produced a plumule, while lot 2 had produced 12 shoots, and lot 3 had produced 19 shoots. It would seem that corn containing a high percentage of water when subjected to germinable conditions is capable of more rapid germination than corn containing a less quantity of initial moisture. However, the absorption of water by the dryer corn was so rapid at 30° that the advantage of the original moisture in lot 3 was not manifest at any period in the test.

The corn of lot 3 had the lowest vitality of any corn in the three lots. This reduction in vitality may have been due to weakness resulting from increased respiratory activity, and possibly also to injury from the cold weather.

The slightly lowered germination of the corn in lot 1 suggests that the vital activities within some of the kernels may have been so reduced as a result of desiccation during storage as to be incapable of resumption when moisture was supplied. The nearest optimum moisture in seed for seed corn storage represented by these three lots of corn is 12.6 percent.

RAPIDITY OF GERMINATION IN THE HIGH AND LOW PROTEIN STRAINS OF CORN

In the water absorption studies it was noted that the Illinois Low Protein corn imbibed water much more rapidly than corn of the Illinois High Protein strain. The same corn was used in a germination test to determine if the increased moisture intake of the low protein corn was an advantage in seedling production, the results being shown in Table 6.

The corn low in protein began germination sooner than the high protein corn at 20°. The former had produced 48 radicles at the

TABLE 6.—*Germination of Illinois High Protein and Illinois Low Protein corn at three different temperatures.*

Temperature	Strain of corn	Percentage germination in 2 days		3 days		4 days		5 days		6 days		8 days		10 days		12 days	
		r	rp	r	rp	r	rp	r	rp	r	rp	r	rp	r	rp	r	rp
20°C.	High Protein	0	0	0	0	0	0	0	0	0	0	0	0	8	0	8	0
	Low Protein	0	0	0	0	0	0	0	0	0	0	0	0	48	0	58	5
25°C.	High Protein	0	0	75	3	18	82	0	100	0	100	0	100	0	100	—	—
	Low Protein	3	0	70	3	40	58	8	92	0	100	0	100	0	100	—	—
30°C.	High Protein	0	0	68	18	18	82	0	100	0	100	0	100	0	100	—	—
	Low Protein	0	0	58	20	48	45	20	80	18	82	5	93	0	98	—	—

end of ten days, as compared with 8 for the latter. The low protein corn developed 5 plumules in 12 days at 20° while the high protein corn produced none. At 25° and 30° the difference is not so striking; in fact, the difference is slightly in favor of the high protein corn. This may be explained by assuming that the absorption of water at 25° and 30° is so rapid that germination is not noticeably checked. Probably, however, if the germination readings had been made at more frequent intervals, an earlier emergence of radicles and plumules might have been noted in the low protein corn. This is in harmony with the early work of de Candolle (4) who found that the time required for germination of seeds increased somewhat as the albumen content of the seeds increased.

The fact that horny type seed will endure cold wet weather, immediately after planting, much better than diseased or starchy seed may be partially explained by the evidence coming out of these investigations. The rate of water absorption is considerably lower in the horny seed than in the starchy seed. This condition tends to delay the germinative processes in the horny seed, so that when cold weather and other unfavorable conditions prevail soon after corn planting, this corn is not as far advanced and therefore not as much subject to injury as the starchy corn.

Notwithstanding the tendency of the high protein corn to start slowly, when once it had started it exhibited seedling vigor far superior to that of the low protein corn. This was shown by a larger number of secondary roots, and greater sturdiness and length of shoot. The shoots of the high protein corn were 86 percent longer at 30°, and 53 percent longer at 25° than those of the low protein corn at these same temperatures. Thus, it seems that high protein content, with its resultant horny character of the endosperm, may be an important factor in seedling vigor. Since this character in corn is co-existent to a high degree with disease freedom (6), the choice of horny seed for planting is a good farm practice.

SUMMARY

Seed corn harvested before complete maturity absorbed water more rapidly and also possessed a greater water absorptive capacity than corn that had been allowed to mature on the stalk.

Corn containing a high proportion of soft starch in the endosperm imbibed water at a more rapid rate than corn of the same variety which possessed an endosperm containing a less proportion of soft starch. Conversely, a high proportion of horny starch in corn reduced water absorption. This held true in corn that had been selected on the germinator for disease freedom and susceptibility, as well as in corn that had been selected for many generations because of its high protein content. Both the high protein corn and the nearly disease-free corn were relatively high in horny material and their rates of water absorption were comparatively low.

Rapidity of water absorption was associated with quick germination. Seedling vigor, however, more often accompanied horniness of the kernel. Mature seed corn germinated somewhat slower, but with more vigor than corn of the same variety harvested before maturity.

Corn containing a large quantity of moisture during storage germinated quicker, but with less vigor than corn containing a smaller quantity of storage moisture. Corn possessing a moisture content of 6.1 percent germinated slower and with a slightly less percentage vitality than corn possessing a moisture content of 12.6 percent.

LITERATURE CITED

1. Atkins, W. R. G. The absorption of water by seeds. *In* Sci. Proc. Roy. Dublin Soc. (n. ser.) 12:35–46. 1909.
2. Brown, Adrian J. and Worley, F. P. The influence of temperature on the absorption of water by seeds of *Hordeum vulgare* in relation to the temperature coefficient of chemical change. *In* Proc. Roy. Soc. London, Series B. 85:546–553. 1912
3. Coffman, F. A. The minimum temperature of germination of seeds. *In* Jour. Amer. Soc. Agron. 15:257–270. 1923.
4. de Candolle, Alphonse. De la germination sous les degres divers de temperature constante. *In* Biblioth. Univ. et Revue Suisse. Arch. Sci. Phys. et Nat. 24:243–282. 1865. English translation *in* Ann. Mag. Nat. Hist., ser. 3, 17:241–265. 1866.
5. Goff, E. S. The effect of continued use of immature seed corn. Wis. Sta. Rpt. 1900:297–299.
6. Holbert, J. R. et al. Bulletin in preparation, Illinois Agricultural Experiment Station.
7. Shull, Charles A. Temperature and rate of moisture intake in seeds. *In* Bot. Gaz. 69:361–390. 1920.
8. Smith, Louie H. Ten generations of corn breeding. Ill. Sta. Bul. 128: 457–575. 1908.

A MINIATURE COPPER CARBONATE DUSTER[1]

A. H. HOFFMAN[2]

Many experiment station workers have found it quite a disagreeable, and even dangerous, task to apply copper carbonate dust to the large number of small lots of seed wheat needed for their rod-row plots. Workers at the California station have found the revolving box mixer shown herewith quite satisfactory for this purpose and also useful for class purposes.

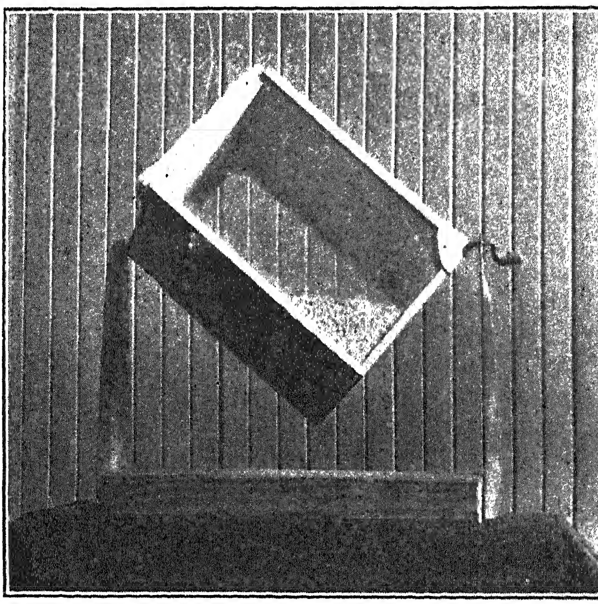

FIG. 1. Miniature dusting machine

This box is six by seven by ten inches inside. The grain should occupy about one-fourth the space inside for best working. Two minutes at about 45 r.p.m. suffices.

The box shown was originally a well-made packing box with a sliding lid. The axis of rotation passes diagonally through two corners. This placing causes the grain and dust to be thrown from end to end of the box at the same time that it rolls over and over. This causes rapid and thorough mixing.

[1]Contribution from the Division of Agricultural Engineering, Branch of the College of Agriculture, University of California, Davis, Calif. Received for publication, May 8, 1924.

[2]Assistant Professor.

Two number twelve wire nails form the journals. One of them also forms the crank. The heads of the two nails are soldered into sheet metal reinforcing pieces which are fastened to diagonal corners of the box. The small loose handle of wood is prevented from coming off by a bead of solder.

Two glass plates on opposite sides enable a good view of what happens inside. One plate, sliding in the grooves originally intended for the wooden lid, furnishes a ready means of putting in and removing the grain. A narrow ribbon of thin felt prevents dust from escaping between the edge of the box and the glass.

Two minutes turning at the speed that gives the most violent tumbling about of the grain is ample to apply the fungicide.

For the best results the grain should occupy not over one-third of the total space inside the mixer.

THE CORRELATION BETWEEN TIME OF GERMINATION, MATURITY, AND YIELD OF CORN[1]

T. B. HUTCHESON AND T. K. WOLFE[2]

The first consideration in the production of corn is yield. The production of high quality corn is frequently largely dependent upon the time of maturity of the crop. The yield and maturity of strains and varieties of corn can be determined by tests in the field. If tests less laborious and time-consuming than field trials could be found which would give some indication as to the yield and maturity of corn, it would be very helpful. The investigation reported in this paper was conducted to study the relation between time of germination and maturity, time of germination and yield, and between yield and maturity.

EXPERIMENTAL WORK

The results reported herein cover a three-year period, 1916 to 1918. In 1916, Boone County White corn was used, while in 1917 and 1918 Silver King corn was used. A number of ears were selected for planting in an ear-to-row test and the germination of each ear was tested before planting. The seed from each ear was planted in duplicate rows. The time of germination was secured by determining the percentage of kernels which had germinated at the end of seventy-two hours. The average of three tests was used in the calculations. Each row was 66 feet long and contained 20 hills of two stalks each.

[1]Contribution from the Department of Agronomy, Virginia Agricultural Experiment Station, Blacksburg, Va. Received for publication May 15, 1924.
[2]Agronomists.

Later in the season the number of plants tasseling and silking on certain dates, the number of days from planting to final maturity of each ear, and the yield were determined for the progeny of each ear. The percentage of tasseling and silking at certain times was calculated by dividing the number of plants which had tasseled and silked on certain dates by the total number tasseling and silking. The final maturity is expressed in days from planting and the yield is expressed in bushels of shelled corn per acre.

Results

The means, standard deviations, coefficients of variability, and coefficients of correlation are given in Tables 1 and 2.

Table 1.—*Means, standard deviations and coefficients of variability for certain characters in the various years.*

Characters	1916	1917	1918
	M	M	M
Tasseling, percentage	53.450± .796	52.180±1.218	23.000±1.025
Silking, percentage	77.000± .844	49.790±1.281	61.270±1.530
Final maturity, days	136.172± .300	————	122.634± .243
Yield, bushels per acre	75.180± .620	54.050± .779	55.500± .501
Time of germination, perc't'ge	70.640±1.308	71.900±1.306	42.600± .851
	σ	σ	σ
Tasseling, percentage	12.370± .562	15.220± .861	13.160± .725
Silking, percentage	13.130± .597	16.000± .906	19.650±1.082
Final maturity, days	4.668± .212	————	3.122± .172
Yield, bushels per acre	9.645± .439	9.735± .551	6.430± .354
Time of germination, perc't'ge	20.340± .925	16.320± .924	10.930± .602
	C	C	C
Tasseling, percentage	23.14 ±1.107	29.17 ±1.786	57.22 ±4.052
Silking, percentage	17.05 ± .798	32.13 ±1.997	32.07 ±1.939
Final maturity, days	2.43 ± .156	————	2.55 ± .140
Yield, bushels per acre	12.83 ± .593	18.01 ±1.052	11.59 ± .647
Time of germination, perc't'ge	28.79 ±1.414	22.70 ±1.349	25.66 ±1.504

Note: In 1916 the percentage of plants that had tasseled and silked, 80 and 90 days, respectively, after planting were used; in 1917 those that had tasseled and silked 93 and 101 days, respectively, after planting; and in 1918 those that had tasseled and silked 59 and 76 days, respectively, after planting.

Table 2.—*Coefficients of correlation between various characters.*

Time of germination, subject correlated with other characters, relative	1916	1917	1918
Tasseling, percentage	—.164±.063	.124±.079	—.015±.078
Silking, percentage	.049±.064	.046±.080	.082±.077
Final maturity, days	—.247±.060	————	—.108±.077
Yield, bushels per acre	.009±.064	.061±.080	—.088±.077
Days to final maturity, subject correlated with other characters, relative			
Tasseling, percentage	.010±.064		—.240±.073
Silking, percentage	—.191±.062		—.518±.057
Yield, bushels per acre	.387±.055		.153±.076

Note: In 1916 there were 110, in 1917 there were 71, and in 1918 there were 75 individuals used in calculating the various constants.

It will be noted that in Table 1 the data on final maturity are not given in all instances. In 1917, owing to an early frost, not all the ear progenies matured and for this reason the data for final maturity were incomplete.

The time of germination, subject, was correlated with various characters, relative, as shown in Table 2. It seems that there is little, if any, relation between time of germination and tasseling, silking, final maturity, and yield. However, the indications are that ears which germinate early, mature late as measured by final maturity of the plants.

Days to final maturity, subject, was correlated with tasseling, silking and yield, relative. The coefficients of correlation with tasseling and silking are negative but somewhat significant in three of the four instances, while in the other instance the coefficient is positive and small. The coefficients of correlation with yield are positive and marked. Other results show that there is a negative relation between yield and tasseling and silking. Such results indicate that plants which tassel and silk early mature late and yield high.

It would be interesting to select plants which reach maturity comparatively early and those which reach this stage of development relatively late and determine the time of tasseling and of silking and the yield of the progenies. One of us (Wolfe) found, as reported in Virginia Agricultural Experiment Station Technical Bulletin 26, that there was no marked difference in yield of corn from seed produced by small stalked and large stalked plants. However, in a previous crop the correlation coefficient between yield of grain per plant and circumference of plant was $.653 \pm .020$. Such a correlation coefficient indicated that the plants producing the highest yield of grain were those possessing stalks with the largest circumferences.

SUMMARY

The coefficients of correlation between the time of germination and tasseling are conflicting. The correlation between the time of germination and silking is too small to be significant and the same may be said of the correlation with yield.

The results indicate that ears which germinate early produce plants which ripen late.

The indications are that the plants which tassel and silk early mature late and yield high.

A RAPID METHOD OF TAKING SOIL SAMPLES FROM FIELD PLOTS[1]

E. P. Deatrick and O. C. Bryan[2]

Last year two pasture experiments were planned to be conducted at the West Virginia experiment station. The departments which suggested the project invited the department of soils to co-operate. Two sets of 44-tenth acre plots have been laid out. Each plot measures 37 x 132 feet, inclusive of the two foot border around it. Inasmuch as there were but two persons to do the sampling, the collection of a large number of samples in the time available became a problem. The need for a more rapid method of taking soil samples from field plots was felt and experimental trials resulted in the development of the method reported here. A diagram of a plot is given in Figure 1, A. By liming quarters b and c and fencing off c and d each plot receives four treatments, viz., limed and unlimed, grazed and ungrazed. It was deemed advisable to collect a sample from each quarter. Only the surface soil was sampled. The method of sampling was as described below. It is offered as a convenient and rapid method for sampling all similar fixed plots.

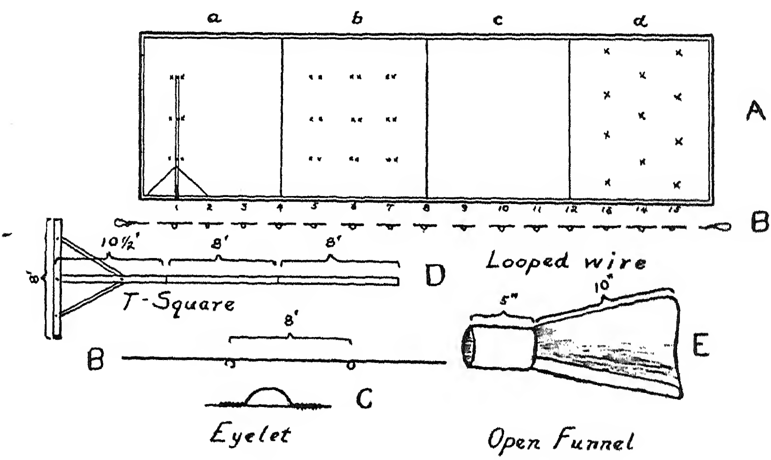

Fig. 1. See text for description of each part.

A long piece of galvanized iron wire was looped, as shown in Figure 1, B, ten feet from a twisted handle and thence every eight feet

[1]Contribution from Department of Soils, West Virginia Agricultural Experiment Station, Morgantown, W. Va. Approved by the Director, May 13, 1924. Received for publication May 22, 1924.

[2]Associate Professor and formerly Assistant Professor, respectively.

for 122 feet. Ten feet from the last loop the wire was cut after a second twisted handle was made. The wire was then 132 feet long—the exact length of the plots. Cooper wire eyelets, as shown in Figure 1, C, were soldered on the first wire that was prepared. It was found later that looping the wire was satisfactory. The loops were drawn to about a quarter-inch opening and a bit of solder was dropped on the back of each of them to prevent closing when the wire was stretched. In the 4th, 8th, and 12th loop there was tied a strip of red cloth. In each of the other loops there was tied a strip of white cloth. The red flags then marked the boundaries between the quarters, a, b, c, and d. The three white flags in each quarter were used to designate the location of lines across the plots along which samples were to be taken.

A T-square, 26¼ ft. long (other dimensions given in figure 1, D) made of 1″ x 2″ furring lumber, was marked 18½ ft. from the head of the "L" so that when the square was placed on the wire stretched lengthwise between two plots this mark designated a point half way across the short way of the plot. Marks also were made eight feet from the center in both direction. Two surface borings were taken at each of the three marks across the plots. All borings were then eight feet apart and ten feet from the end of the plot, i. e., eight feet from the border. The borings were turned off the auger into the specially prepared galvanized iron open funnel (Figure 1, E) handled by a young lad who had placed a previously numbered bag over its throat. The "T" square was moved to the next flag a distance of eight feet and borings obtained as before. After the next move the bag was dropped near the wire and exchanged for an empty one. The position of the red flag being skipped, the borings were taken after the "T" was centered on the next white flag. When the borings in the last quarter were completed the "T" was turned so that while the head remained on the wire the arm stretched over the adjacent plot. The borings were then continued in like fashion, so that one placement of wire served for the sampling of two plots.

In practice, it was found possible with two men to sample the soil on two plots, i. e., 1/5 acre, in about 30 minutes. This means that in 30 minutes the wire was placed, 144 borings were made, and the lad (who carried the numbered bags for two plots in his belt) was checked to see that the correct bag for the quarter section being sampled was placed on the funnel. The filled bags later were gathered, ied, and taken to the laboratory where the soils were air dried, ulverized in pebble mill, and placed in storage in screw top jars.

It was found simplest to number the quarter plots serially with the smallest number at the top (uphill) of the tenth acre plot. By marking the arm of the T-square differently or by knotching it and tying two colors of flags on it, it would be a simple matter to work out any method of sampling. Alternate sampling, as shown in A, d, was tested out by tying blue and white flags on the arm of the "T" and upon the wire. The red flags were retained to mark the quarters. When the "T" was on the white flag, samples were taken at the white flags on the arm of the "T." Then the next move brought the "T" to a blue flag and samples were taken at the blue flags on the arm.

METHODS OF MAKING DETERMINATIONS AND INTERPRETING RESULTS IN GRAIN GRADING[1]

A. C. Arny and C. S. Dorchester[2]

PURPOSE OF THE INVESTIGATIONS

The work which forms the basis of this paper was planned and carried out with the idea of securing data to answer questions arising in the classroom and in discussions with men engaged in the grain trade regarding phases of grain grading on which there appeared to be no published data.

A statistical study of the relation of size of sample to the reliability of determinations, which not only points out the most desirable size or sizes of samples but at the same time gives the facts on which the decision is based, should aid in securing greater uniformity in the size of the samples used.

It appeared desirable to know whether samples of a size adequate for determinations on grain of relatively poor quality, because of the presence of comparatively large amounts of heat damage or foreign material, would serve as well in grain of good quality where the damage or injurious material was present in small amounts.

The matter of the manner of securing samples for determinations appeared to warrant sufficient investigation to answer one or two questions, at least. Is the accuracy increased by combining two or more small samples taken in regular order from different parts of the original sample, as compared with combining small samples taken from the same location which amounts to the same thing as taking the

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one larger sample? Some workers make a practice of taking the duplicate sample from the other half of the original sample in preference to using the other half of the smaller sample secured for the first determination. Is this practice worth the time it takes to cut the other half of the original sample down to proper size?

In all probability the unequal cutting of samples by some of the Boerner samplers in no way affects the grade; but some workers believe that results are affected and sufficient work to warrant a decision in this matter appeared desirable.

Then, there comes up frequently the question of how close the decisions can be on lots of grain that are near the grade maximum, particularly where difference between two grades is as little as one-tenth of one percent. This always brings with it the matter of tolerance in the grading of samples of this kind.

PREVIOUS WORK

Frank and Campbell (1)[3] working with corn, oats, wheat, and grain sorghums concluded that variations in samples from the same lot of grain may occur in the laboratory owing to the methods of cutting down the original sample to approximately 1,000 grams. The divider was used throughout the test. The variations investigate consisted of differences in the methods of taking the samples from the divider pan. Out of 40 samples of wheat tested for dockage, 21 varied as much as one-half of one percent and eight varied one percent or more from the true divider sample. The variations resulting from incorrect methods of sampling were comparatively larger when the dockage consisted of material much larger or smaller than the wheat. In oats the range, while not so great as in wheat, was large enough to cause an error of one or two grades. Similar variations occurred in the work with corn and grain sorghums. These investigators recommend the establishment of a system of tolerances, or range of variation, in the form of a definite percentage but do not present any data on which such a system could be based. It is suggested that the personal opinion factor, which is apt to play an important part in the case of "line" samples, will be largely eliminated by such a system.

Phillips (2) summarizes the findings of workers in the United States Department of Agriculture with respect to the size of sample to be used in determining commercial grades as follows:

In *wheat*, determinations for class, odor, inseparable stones, and "treated" should be made on the sample as a whole; dockage, weight, garlic, and live

[3]Reference by number is to "Literature Cited," p. 505.

weevils on approximately 1000 grams; damaged, heat damaged, foreign material, and smut balls on not less than 50 grams; color and texture on not less than 25 grams; admixtures of other wheats on from 10 to 25 grams. If it is necessary to make separations on treated wheat not less than 25 grams should be used.

In *corn*, determinations for cracked corn and foreign material should be made on approximately 500 grams, damaged, heat damaged and other colors on approximately 250 grams of clean corn.

In *oats*, determinations for general appearance should be made on the sample as a whole, sound cultivated oats, heat damaged, foreign material, wild oats, and other colors on not less than 25 grams. When oats contain an unusual amount of foreign material, approximately 250 grams of the sample should be used in the determination of that factor.

The instructions of the Department with regard to the handling of "line" samples, as given by Phillips, are as follows:

"When the grade of any lot of grain is determined by a narrow margin of a percent, on a single factor, make another determination and base the grade on the average of the two determinations."

Under the rules of the Association of Official Seed Analysts of North America (3), (7), a certain latitude of variation, or tolerance, must be allowed when analyzing samples from lots that have been previously tested or that have been put on the market under certain guarantees. This tolerance is to cover the natural variation which may occur between different samples of the same lot. For each determination of tolerance the sample shall be considered as being made up of two parts: (1) the element being considered and (2) the balance of the sample. For example, in determining the tolerance for weed seeds the sample shall be considered as being made up of (1) weed seeds and (2) everything not weed seeds. The tolerance allowed for pure seed, weed seed, inert matter, and seeds of other cultivated plants shall be one-tenth of one percent plus 10 percent of the lesser part. In the case of a sample containing 2 percent weed seeds, the tolerance allowed would be 0.1 percent plus 0.2 percent, a total of 0.3 percent.

MATERIALS AND METHODS

For the work on percentages of heat damage in wheat, bulk lots were prepared by thoroughly mixing badly heat-damaged spring wheat with clean dark hard spring wheat which contained no starchy kernels as follows:

Series	Sound wheat grams	Heat damage grams	Heat damage percent
A	3196.6	3.2	0.1
B	3193.6	6.4	.2
C	3184.0	16.0	.5

D	3168.0	32.0	1.0
E	3104.0	96.0	3.0

Each lot was put through the Boerner sampler 5 times, recombining it thoroughly in a large pan after each time.

For the work with wheat containing cockle and vetch lots were made up as follows:

Series	Wheat	Foreign Material	
	grams	grams	percent
A	3184	16 cockle	0.5 cockle
B	3168	32 "	1.0 "
C	3184	16 vetch	0.5 vetch
D	3168	32 "	1.0 "

Each series for determinations of percentages of heat damage in wheat was divided with the regulation size Boerner sampler first into samples of 100-gram size which were given consecutive numbers from 1 to 32. Then each 100-gram sample was divided into samples of approximately 2.5 grams. In order to be able to recombine the 12.5-gram samples into precisely the same 25-gram samples from which they came originally and the 25- and 50-gram samples into 50- and 100-gram samples, respectively, in the same manner, a record was kept of the left (small spout) and right (large spout) according to the following plan:

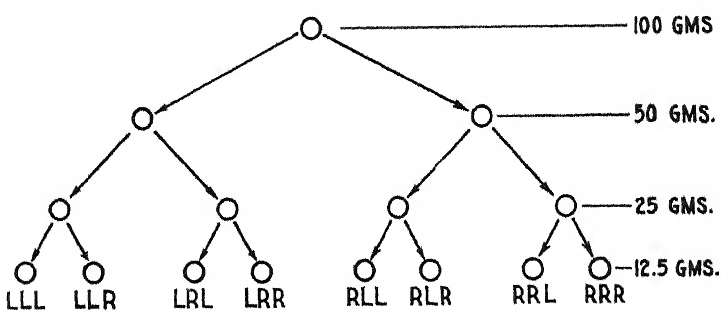


FIGURE 1. Plan of designating the 12.5-gram samples so that they could be recombined into precisely the same larger samples from which they came.

Each sample was lettered according to the direction of the cut and numbered. The 12.5-gram sample at the left was from the first 100-gram lot in Series A and numbered AILLL and the other AILLR. The first one was cut three times to the left and the second one twice to the left and once to the right. The 12.5-gram samples for each series were also numbered consecutively from 1 to 256.

The same plan was followed in cutting the wheat containing the cockle and vetch.

A careful determination of percentage of heat damage was made on each of the 256 samples of 12.5-gram size in each of the five lots of wheat made up for that purpose. Foreign material percentage determinations were made on each of the 50-gram samples containing cockle and vetch.

All 12.5-gram wheat samples containing heat damage and all heat damage, cockle, and vetch were weighed on a Troemner 542 balance. All weighings and computations have been checked.

For the interpretation of the results the following statistical constants were worked out according to accepted methods: (4) (a) The mean or average for the number of determinations on each of the sizes of sample and for each grade. (b) The standard deviation which gives the variation on either side of the mean or average in units of the same denomination as the mean. Since the means are given in percent in all the work included here, the standard deviation is in percent also. The standard deviation is used to compare the variability of determinations having approximately the same mean. For comparisons of variability between determinations on grain having different average percentages of heat damage or foreign material some other constant than the standard deviation is necessary. (c) The coefficient of variability which is derived by dividing the standard deviation by the mean and is always expressed in percent serves admirably for this purpose. (d) The probable error is a mathematical expression of the reliability of the determinations expressed by any mean, standard deviation, or coefficient of variability given (6). It is employed mainly in judging of the value or significance of differences in the variability of determination as expressed by the two standard deviations. (e) The probable error of a difference is equal to the square root of the sum of the squares of the probable errors of two constants for which the difference is secured. (f) The significance of a difference is obtained by dividing it by its probable error and looking up the odds in tables available for this purpose (5). A difference of .0180 ± .0060 between two standard deviations gives a quotient of 3 when the difference is divided by the probable error. Looking up 3 in the tables gives odds of 22.26 to 1 against this difference being due to normal variation. Odds of 30 to 1 or 3.2 times the probable error are accepted in this work as giving reasonable certainty.

RESULTS OF THE WORK

The several phases of the work were taken up in such order that the results secured from the completion of each part would be available in the interpretation of the results for the others which remained to be done.

RELATION OF DIRECTION OF CUT IN THE BOERNER SAMPLER TO VARIABILITY OF PERCENTAGES OF HEAT DAMAGE IN WHEAT

Frequent statements by men who use samplers that they believed that it might make a difference as to which side of the sampler the material for the determination comes from led to a check of this first, although from the construction of the device a real difference in variability in such determinations did not appear probable. Three samplers were used. Of wheat containing approximately 3 percent heat damage there were available thirty-two 12.5-gram samples each having (a) three left cuts, (b) three right cuts, (c) one right and two lefts, (d) one left and two rights, (e) two lefts and one right. The means, standard deviations, and coefficients of variability have been worked up for these and are presented in Table I, together with the differences between the standard deviations with their probable errors and the odds.

The difference between the standard deviations in the first comparison where the samples are cut three times to the right and three times to the left, respectively, is only 1.3 times its probable error which gives odds of 1.63 to 1 against such a difference being due to normal variation. These odds are considerably less than the 30 to 1 which have been accepted as giving reasonable certainty. The other two comparisons have less than three cuts in any one direction and less difference would be expected than in the first comparison and this is what the results show. The results with the limited number of samplers indicate that similar results as to grade may be expected regardless of the side of the sampler from which the material is taken and that is the basis on which further work reported in this paper is carried out.

METHOD OF TAKING SAMPLES FOR DETERMINATIONS

The opinion has been often expressed that in making more than one determination it is more desirable to secure each of the samples from a different part of the entire sample than to divide down the one-half only until the desired sample or samples of the right size are secured. Following this method the original sample of say 1,000 grams would be divided into two samples of 500 grams each and then from each of the 500 gram samples one or more of the desired

TABLE 1.—*Comparison of the variability of percentage determinations of heat damage in wheat.*

Series E	Mean	Standard deviation	Differences between the standard deviations for left and right cuts	Difference divided by probable error	Odds against such differences being due to normal variation
LLL	3.1875±.0723	.6061±.0511			
RRR	2.9250±.0843	.7067±.0596	.1006±.0785	1.3	1.63 to 1
RLL	3.0875±.0793	.6651±.0561			
LRR	3.0125±.0866	.7262±.0612	.0611±.0830	0.7	—
LLL	3.1875±.0723	.6061±.0511			
LLR	2.9937±.0813	.6819±.0575	.0758±.0769	1.0	1 to 1

TABLE 3—*Summary of differences between the standard deviations divided by the probable errors derived determiniations of heat damage on samples increased in size (1) and (2) by combining contiguous portions.*

Methods of combining samples to increase size	Size of samples combined	Size of samples used	Number of determinations	Differences in standard deviations divided by the probable error				
				One-tenth percent	Two-tenths percent	Five-tenths percent	One percent	Three percent
Contiguous halves.......	12.5	25.0	128					
Regularly distributed....	12.5	25.0	128	0.1	0.2	1.5	0.7	0.1
Contiguous fourths......	12.5	50.0	64					
Regularly distributed....	12.5	50.0	64	0.3	1.3	0.3	1.4	0.4
Contiguous halves.......	25.0	50.0	64					
Regularly distributed....	25.0	50.0	64	1.1	0.3	0.7	0.2	0.8

size would be secured, as contrasted to the usual method of dividing down one of the 500 gram samples until the desired number of samples of the proper size is secured.

Since grain taken for percentage determinations is usually well mixed before the samples are drawn and the sampler mixes it further as the grain goes through, it appeared probable that approximately the same variability would occur regardless of which of the methods of taking the sample was followed. However, samples 25 and 50 grams in size were made up by (a) combining the weights of contiguous portions according to the following plan:

Designation of the 12.5-gram samples	12.5 grams Total weight grams	12.5 grams Heat damage grams	25 grams Total weight grams	25 grams Heat damage grams	50 grams Total weight grams	50 grams Heat damage grams	100 grams Total weight grams	100 grams Heat damage grams
1 LLL	12.35	.02	—	—	—	—	—	—
1 LLR	12.76	.00	25.11	.02	—	—	—	—
1 LRL	13.00	.00	25.41	.03	50.54	.05	—	—
1 LRR	12.41	.03	—	—	—	—	100.97	.12
1 RLL	11.90	.00	—	—	—	—	—	—
1 RLR	12.60	.00	24.50	.00	—	—	—	—
1 RRL	13.10	.03	25.95	.07	50.45	.07	—	—
1 RRR	12.85	.04	—	—	—	—	—	—

and (b) by averaging the percentages of heat damage from regularly distributed samples taking numbers 1 and 129, 2 and 130, etc., where two were averaged, or numbers 1, 65, 129, and 193, etc., where four were averaged until the 256 determinations on the 125 grain samples for each grade had all been used in making up 128 or 64 percentages. The same method was followed in making up the percentages for the fifty gram samples.

The distribution of the samples according to percentage of heat damage contained is given in Table 2, for grades one and two; together with the standard deviations, differences between the standard deviations for the determinations on the samples derived by (a) combining contiguous portions and (b) regularly distributed, differences divided by the standard deviations, and the odds.

For the same size of sample secured by the two methods the distribution is very similar in each case. The standard deviations for each size of sample secured by the two methods are so close together that the differences between them are negligible when interpreted in the form of odds.

The odds against the differences between the standard deviations compared for the five grades are summarized in Table 3.

It will be noted that the results for the wheat containing 0.5, 1.0, and 3.0 percent of heat damage are similar to those secured for the samples of the same sizes containing 0.1 and 0.2 percent heat damage.

It is therefore clear that determinations made on contiguous portions of a sample are as accurate as those made on regularly distributed portions. No greater accuracy is secured by cutting down each of the two halves of a 1,000-gram sample and taking one of the duplicates from each. Therefore, in the work on size of sample the results are assembled without regard to whether the determinations were made on contiguous or regularly distributed portions.

SIZE OF SAMPLE

For the study of the relation of size of sample to variability of percentage of heat damage, there is available the results from the work with samples varying in size from 12.5 to 200 grams for wheat containing approximately one-tenth, two-tenths, five-tenths, one and three percent of damage.

The distributions for the samples of the several sizes up to and including 100 grams in classes according to the percentage of heat damage as given in Table 4 bring out sharply the relation between size of sample and range of variability.

It will be noted that for the 12.5 gram size there are a large number of samples with no heat damage. This is particularly noticeable in the wheat containing only one-tenth percent heat damage where the presence in this size of sample of a kernel of heat damage weighing .03 grams make 0.24% and grade number three. With the increase in size of sample, the range of variability decreased markedly. The actual range of variability as given in Table 4 makes it easier to appreciate the significance of the data given in Table 5.

In this table the variability of the determinations for heat damage are expressed by the standard deviation in the same denominations as the means which in this case are in percent.

These standard deviations are of value in making comparisons of the variability of the determinations on each size of sample within any one grade. They cannot be used in making comparisons of the variability of determinations on the same or different weights of samples in the different grades of wheat.

The standard deviation for the smaller size within any one grade has been subtracted from the standard deviation for the sample next larger in size giving the differences. The probable errors for each of these differences have been determined. These differences with their probable errors are given in the third column from the right. Each difference has been divided by its probable error and the odds against such a difference being due to normal variation have been obtained from the table of odds (5). These differences divided

TABLE 2.—*Comparison of the reliability of determinations of percentages of heat damage on samples made up from smaller samples (a) Contiguous to each other and (b) regularly distributed throughout the mass.*

Amount of heat damage in percent	Method used in increasing the size of the samples	Weight of samples combined grams	Weight of samples used	Number of samples used	Number of samples with heat damage in tenths of percent 0	.03	.09	.15	.21	.27	.33	.39	.45	.51	.57	Standard Deviations	Differences between the standard deviations	Differences between standard deviations divided by their probable errors	Odds against such differences being due to normal variations
One-tenth percent Grade 1	Contiguous halves	12.5	25.0	128	50	2	32	19	16	4	1	1	2	1		.1015±.0043	.0010±.006	0.1	—
	Regularly distributed	12.5	25.0	128	51	2	30	23	9	5	3	4	1			.1005±.0043			
	Contiguous fourths	12.5	50.0	64	8	15	21	14	3	1	2					.0700±.0042	.0021±.006	0.3	—
	Regularly distributed	12.5	50.0	64	8	14	21	16	1	2	2					.0721±.0043			
	Contiguous halves	25.0	50.0	64	8	15	21	14	3	1	2					.0700±.0042			
	Regularly distributed	25.0	50.0	64	11	13	22	5	9	3	1					.0768±.0046	.0068±.0062	1.10	1.18 to 1
Two-tenths percent Grade 2	Contiguous halves	12.5	25.0	128	24	0	21	16	23	17	12	6	3	3	3	.1402±.0059	.0019±.0084	0.2	—
	Regularly distributed	12.5	25.0	128	20	0	23	16	22	16	12	8	3	6	2	.1421±.0060			
	Contiguous fourths	12.5	50.0	64	6	0	9	13	14	13	6	0	3	1		.1082±.0065	.0112±.0087	1.3	1.63 to 1
	Regularly distributed	12.5	50.0	64	2	4	7	11	19	11	5	4	1			.0970±.0058			
	Contiguous halves	25.0	50.0	64	6	0	9	13	14	13	6	0	2	1		.1082±.0065	.0033±.0091	0.3	—
	Reglarly distributed	25.0	50.0	64	1	5	11	17	11	4	8	7				.1049±.0063			

TABLE 4.—*Effect of increase in size of sample in the reduction of the variability of percentage of heat damage in wheat containing one-tenth, two-tenths and five-tenths percent of damaged grain.*

Amount of heat damage in original lot	Weight of Samples Grams	Number of Samples	0	.03	.09	.15	.21	.27	.33	.39	.45	.51	.57	.63	.69	.75	.81
One-tenth percent	12.5	256	165	0	3	15	32	18	7	4	5	3	1	0	1	0	2
	25.0	128	50	2	32	19	16	4	1	1	2	1					
	50.0	64	8	15	21	14	3	1	2								
	100.0	32		10	13	6	2	1									

Amount of heat damage in original lot	Weight of Samples Grams	Number of Samples																	
Two-tenths percent	12.5	256	0	.03	.09	.15	.21	.27	.33	.93	.45	.51	.57	.63	.69	.75	.81	.87	.93
	12.5	256	104	0	1	23	31	23	14	19	9	15	9	2	1	2	2	0	1
	25.0	128	24	0	21	16	23	17	12	6	3	3	3						
	50.0	64	6	0	9	13	14	13	6	0	2	1							
	100.0	32			5	8	10	8	0	1									

Amount of heat damage in original lot	Weight of Samples Grams	Number of Samples	0	.04	.12	.20	.28	.36	.44	.52	.60	.68	.76	.84	.92	1.0	1.08	1.16	1.24	1.32	1.40	1.48	1.56	1.64	1.72
Five-tenths percent	12.5	256	27	0	5	35	25	17	29	29	20	14	16	11	3	7	1	5	5	2	2	2	0	0	1
	25.0	128	1	0	7	8	14	21	17	17	12	12	5	6	4	2	2								
	50.0	64			2	1	3	9	16	13	9	3	5	2	1										
	100.0	32					2	5	7	10	4	2	2												

by their probable errors and the odds are given on the last two columns to the right.

Considering odds of 30 to 1 as reasonably certain, it is clear that for all the grades of wheat the 50-gram sample which is being used largely in the grading work as carried out at present gives definitely more reliable results than any sample of smaller size.

Three of the determinations included in Table 4 which were made on samples of 100-gram size are definitely more reliable than those made on 50-gram samples. In all sixteen comparisons were made of the variability when these two sizes of samples were used. In eleven out of sixteen comparisons, the determinations on the 100-gram samples were more reliable than those on the 50-gram samples.

In five of the ten comparisons made between samples 100 and 200 grams in size, there were significant differences in favor of the larger samples.

In addition to the determinations for percentage of heat damage in wheat, there were sixty-four determinations each made on wheat containing five-tenths and one percent of cockle and one percent of vetch. The percentages for the 50-gram samples were combined so as to give determinations on samples 100 and 200 grams in size, respectively.

The odds in favor of the 100-gram size of sample as compared with the 50-gram size are 1050 to 1, 54 to 1 and 65 to 1. This indicates that in each of the three cases the 100-gram sample gave the most reliable results.

In one comparison out of three, the 200-gram sample proved more reliable than the sample 100 grams in size.

The wide variability of determinations for heat damage and foreign material other than cereal grains shown when samples less than 50 grams in size were used and the preponderance of the evidence in favor of the 100- as compared with the 50-gram sample should serve to remind continually anyone whose duty it is to make these determinations that the matter of using sufficiently large samples is of prime importance. Small samples make the work of ascertaining percentages quicker and easier, but this is at a distinct sacrifice in accuracy because such samples are not as representative of the entire lot as larger samples.

BEST OF TECHNIQUE REDUCES BUT DOES NOT OBVIATE VARIABILITY

It has been shown that the variability of determinations for heat damage and foreign material other than cereal grains may be reduced to a very large degree by using 100-gram samples in preference

TABLE 5.—*Effect of increase in size of sample by recombining halves of original samples in the same way as they were divided out on the variability of percentages of heat damage in wheat.*

Maximum percent of heat damage in grades of wheat	Weight of sample grams	Number of determinations	Mean	Standard Deviation	Difference between the standard deviation for each group and that next larger in size	Difference divided by probable error	Such difference being due to normal variation
One-tenth percent	12.5	256	.1066±.0062	.1476±.0004			
Grade 1.........	25.0	128	.0948±.0061	.1015±.0043	.0461±.0062	7.4	1,000,000 to 1
	50.0	64	.0989±.0059	.0700±.0042	.0315±.0060	5.3	5,000 to 1
	100.0	32	.0984±.0066	.0557±.0047	.0143±.0063	2.3	8 to 1
	200.0	16	.0956±.0050	.0295±.0035	.0262±.0058		
Two-tenths percent	12.5	256	.2073±.0085	.2006±.0060			
Grade 2.........	25.0	128	.1941±.0084	.1402±.0059	.0604±.0084	7.2	500,000 to 1
	50.0	64	.1983±.0091	.1082±.0065	.0320±.0088	3.6	65 to 1
	100.0	32	.1969±.0083	.0695±.0059	.0387±.0088	4.4	330 to 1
	200.0	16	.1894±.0083	.0490±.0058	.0205±.0082		
Five-tenths per cent	12.5	256	.4883±.0140	.3324±.0099			
Grade 3.........	25.0	128	.4887±.0135	.2269±.0096	.1055±.0138	7.6	5,000,000 to 1
	50.0	64	.4994±.0134	.1594±.0095	.0675±.0135	5.0	1,350 to 1
	100.0	32	.4938±.0137	.1145±.0097	.0449±.0136	3.3	37 to 1
	200.0	16	.4975±.0116	.0686±.0082	.0459±.0126		
One-percent	12.5	256	.9358±.0183	.4338±.0129			
Grade 4.........	25.0	128	.9281±.0185	.3110±.0131	.1228±.0184	6.7	100,00 to 1
	50.0	64	.9375±.0195	.2315±.0138	.0795±.0190	4.2	215 to 1
	100.0	32	.9375±.0193	.1616±.0136	.0699±.0194	3.6	65 to 1
	200.0	16	.9375±.0272	.1616±.0193	.0000±.0000		
Three-percent	12.5	256	3.0383±.0284	.6746±.0201			
Grade 5.........	25.0	128	3.0328±.0295	.4946±.0209	.1800±.0290	6.2	25,000 to 1
	50.0	64	3.0500±.0311	.3692±.0220	.1254±.0303	4.1	175 to 1
	100.0	32	3.0250±.0371	.3113±.0263	.0579±.0343	1.7	3 to 1
	200.0	16	3.0500±.0348	.2062±.0246	.1151±.0360		

to samples of smaller size. The use of 200-gram samples reduced the variability still farther in only fifty percent of the cases and the labor of making the determinations on this size of sample makes its use impractical.

After the most careful work both in securing the samples and in making the determinations, there still remained a range of variability on either side of the grade maximum. This variability may be considered to best advantage by using the coefficient of variability of the determinations given in Tables 7 and 8 for each of the different weights of samples for each grade of wheat. Since the coefficient of variability is given in percentage of the mean or average, it may be used in making comparisons of the variability of the determinations secured from the use of the same or different weight of sample in the different grades of wheat.

Comparison of the coefficients of variability for the determination on any particular weight of sample brings out the point that there is the greatest variability where the percentage of heat damage or of cockle or vetch is the lowest, i. e., in the best grades of wheat. In the determinations for heat damage where the 100-gram sample was used the variability in percent as expressed by the coefficient of variability decreases from 56.0% in grade one to 35.2% in grade two, 23.18% in grade three, 17.23% in grade four, and 10.31% in grade five. Essentially, this means that the use of the 100-gram sample in determining percentages of heat damage in wheat containing only approximately one-tenth of one percent of this form of damage, gives considerably more variable results than in wheat containing more heat damage. This is due to the fact that in the wheat containing the larger amounts of heat damage, the 100-gram sample is more representative of the average than it is in the wheat containing a small amount of damage.

The conclusion should not be reached that the use of a 12.5-gram sample in the lower grades is justified by the fact that the variability for the 100-gram sample is 56.60% in grade one wheat and the variability for the 12.5-gram sample is 22.20% in grade five wheat. In view of the fact that even when the 100-gram sample was used considerable variation still occurred, the only logical procedure appears to be to make due allowance for it. By making use of the coefficient of variability, allowance can be made for this variability in the following manner:

Taking the 100-gram sample as the most desirable to use, the variability of the determinations for heat damage in wheat containing one-tenth percent of this form of damage was 56.60% or approxi-

TABLE 6.—*Effect of increase in size of sample on the variability of percentages of cockle and wild vetch in wheat.*

	Weight of Sample grams	Number of determinations	Means	Standard deviation	Differences between the standard deviation for each group and that next larger in size	Differences divided by their probable error	Odds against such difference being due to normal variation
Cockle Five-tenths Percent	50	64	.5259±.0078	.0925±.0055			
	100	32	.5269±.0067	.0566±.0048	.0359±.0073	4.9	1051 to 1
	200	16	.5231±.0080	.0476±.0057	.0090±.0075	1.2	1.4 to 1
One percent	50	64	1.0312±.0125	.1480±.0088			
	100	32	1.0284±.0125	.1049±.0088	.0431±.0124	3.5	54 to 1
	200	16	1.0275±.0136	.0807±.0096	.0242±.0130	1.9	4 to 1
Vetch One percent	50	64	1.0256±.0165	.1953±.0116			
	100	32	1.0256±.0163	.1363±.0115	.0590±.0163	3.6	65 to 1
	200	16	1.0219±.0129	.0767±.0091	.0596±.0147	4.0	142 to 1

mately 28.30% on either side of the means or the present grade limit of one-tenth of one percent. 28% of 0.1% is .028%, which added to the mean or present grade limit of 1.1% gives .128% and subtracted from 0.1% gives .072%. .072% therefore marks the approximate range limits in % of the determinations on wheat containing 0.1% heat damage above the grade limit and 0.128 marks the approximate range limits in percent below the grade limit. For convenience this may be made in round numbers 0.07% above and 0.13% below. This means that the chances are even that any one sample taken to determine the grade of this wheat might show a percent of heat damage from 0.1 to .07% on one side or from 0.1 to 0.13 on the other side of the grade maximum. Making due allowance for variability then, a sample of the lot of wheat made up to 0.1% of heat damage analyzing 0.13% from one or two determinations would still put the lot in grade one.

This suggests percentages of tolerance when determinations are made on a single sample or on duplicate samples to ascertain the grades of a lot of grain which indicate that it is near a grade maximum. Obviously, to be equitable the percentage of tolerance must be based on work that has ascertained fairly accurately the variability in percent for the factors in the various grades where the tolerance is to be applied.

Until further work indicates that these figures should be changed, the percentages given in the third column from the right in Tables 7 and 8, headed variation on either side of the mean in percent, are suggested for consideration in connection with determinations for heat damage and foreign material other than cereal grains in wheat.

On the supposition that the 100-gram sample will be used very largely, the suggested tolerance in round numbers is 30% for wheat near the grade limits of number one, 20%, 10%, 10% and 5%, respectively, for wheat near grade limits for number two to five respectively for heat damage and 5% for foreign material other than cereal grains. With samples of smaller size, the larger tolerances will necessarily need to be applied. For 50-gram samples the suggested tolerances are 35% for wheat containing approximately 0.1% heat damage, 25%, 15%, 10% and 5% respectively for grain containing approximately 0.2%, 0.5%, 1.0% and 3.0% of heat damage and 10% and 5% respectively for grain containing approximately 0.5% and 1.0% of foreign material other than dockage.

In Figure 2, there is presented graphically the suggested range of tolerance beyond the grade limits for determinations as made on

TABLE 7.—*Comparison of the variability of percentage determinations of heat damage in wheat containing approximately one, two, and five tenths, one and three percent for samples, 12.5, 25, 50, 100 and 200 grams in size together with the range of variability below the present grade maxima when samples of the given weights were used.*

	Weight of sample grams	Number of determinations	Means	Standard deviation	Coefficient of Variability %	Variation on either side of the mean %	Present grade maxima for for heat damage %	Range of variability below grade maxima
One tenth percent Grade 1	12.5	256	.1066±.0062	.1476±.0044	138.4615±[1]	69	0.1	0.169
	25.0	128	.0948±.0061	.1015±.0043	107.0675±[1]	54	.1	.154
	50.0	64	.0989±.0059	.0700±.0042	70.7786±[1]	35	.1	.135
	100.0	32	.0984±.0066	.0557±.0047	56.6057±6.1130	28	.1	.128
	200.0	16	.0956±.0050	.0295±.0035	30.8577±4.0141	15	.1	.115
Two tenths percent Grade 2	12.5	256	.2075±.0085	.2006±.0060	96.7680±[1]	48	0.2	0.297
	25.0	128	.1941±.0084	.1402±.0059	72.2308±[1]	36	.2	.272
	50.0	64	.1983±.0091	.1082±.0056	54.5638±4.1086	27	.2	.254
	100.0	32	.1969±.0083	.0695±.0059	35.2971±3.3261	18	.2	.236
	200.0	16	.1894±.0083	.0490±.0058	25.8712±3.2843	13	.2	.226
Five tenths percent Grade 3	12.5	256	.4883±.0140	.3324±.0099	68.0729±2.8164	34	0.5	0.670
	25.0	128	.4887±.0135	.2269±.0096	46.4068±2.3400	23	.5	.615
	50.0	64	.4994±.0134	.1594±.0095	31.9183±2.0876	16	.5	.580
	100.0	32	.4938±.0137	.1145±.0097	23.1875±2.0574	12	.5	.560
	200.0	16	.4975±.0116	.0686±.0082	13.7889±1.6751	7	.5	.535
One percent Grade 4	12.5	256	.9398±.0183	.4338±.0129	46.1588±1.6431	23	1.0	1.23
	25.0	128	.9281±.0185	.3110±.0131	33.5093±1.5633	17	1.	1.17
	50.0	64	.9375±.0195	.2315±.0138	24.6933±1.5594	12	1.	1.12
	100.0	32	.9375±.0193	.1616±.0136	17.2373±1.4959	9	1.	1.09
	200.0	16	.9375±.0272	.1616±.0193	17.2373±2.1155	9	1.	1.09
Three percent Grade 5	12.5	256	3.0383±.0284	.6746±.0201	22.2032±0.6937	11	3.0	3.33
	25.0	128	3.0328±.0295	.4946±.0209	16.3084±0.7056	8	3.	3.24
	50.0	64	3.0500±.0311	.3629±.0220	12.1049±0.7322	6	3.	3.18
	100.0	32	3.0250±.0371	.3113±.0263	10.3160±.08789	5	3.	3.15
	200.0	16	3.0500±.0348	.2062±.0246	6.7607±0.8061	3	3.	3.09

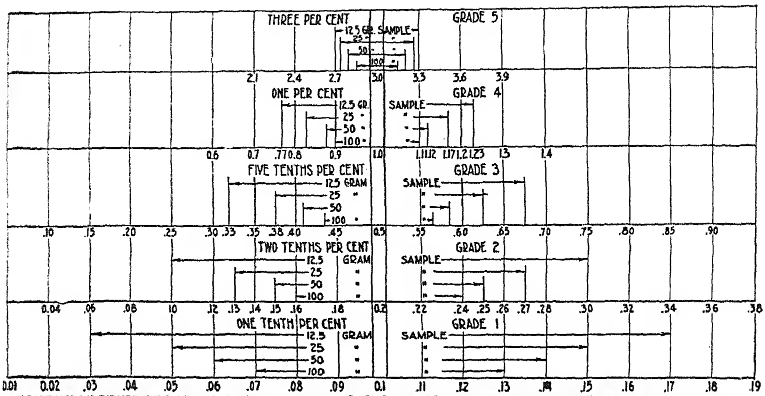
[1]Not calculated.

TABLE 8.—*Comparison of the variability of percentage determinations of foreign material other than cereal grains in wheat containing five-tenths and one percent for samples 50, 100 and 200 grams in size together with the range of variability below the present grade maxima when samples of the grain weights were used.*

Percent of foreign material other than cereals in wheat	Weight of sample grams	Number of determinations	Means	Standard deviations	Coefficients of variability	Variation on either side of the the mean %	Present grade maxima for foreign material other than cereals %	Range of variability below present grade maxima
Cockle	50	64	.5259±.0078	.0925±.0055	17.5889±1.0807	9	0.5	.545
Five-tenths per cent	100	32	.5269±.0067	.0566±.0048	10.7421± .9161	5	.5	.525
Grade 1	200	16	.5231±.0080	.0476±.0057	9.0996±1.0850	5	.5	.525
One percent	50	64	1.0312±.0125	.1480±.0088	14.3522± .8731	7	1.0	1.07
Grade 2	100	32	1.0284±.0125	.1049±.0088	10.2003± .8689	5	1.0	1.05
	200	16	1.0275±.0136	.0807±.0096	7.8540± .9364	4	1.0	1.04
Vetch	50	64	1.0256±.0165	.1953±.0116	19.0425±1.1758	10	1.0	1.10
One percent	100	32	1.0256±.0163	.1363±.0115	13.2898±1.1402	7	1.0	1.07
Grade 2	200	16	1.0219±.0129	.0767±.0091	7.5056± .8949	4	1.0	1.04

samples of varying size for wheat containing approximately 0.1%, 0.2%, 0.5%, 1.0% and 3.0% of heat damage as given in the last column to the right in Tables 7 and 8.

The present limits for each grade are given in the column in the center and to the right are given the ranges of tolerance below the



VARIATION ON EITHER SIDE OF THE GRADE LIMITS OF PERCENTAGES OF HEAT DAMAGE IN WHEAT FOR SAMPLES OF DIFFERENT SIZES.

FIGURE 2

grade limits for the different weights of samples. As is indicated the ranges of tolerances are drawn to scale which brings out the facts that the suggested tolerances in percent decrease (a) as the percentages of heat damage in the wheat increase and (b) as the sizes of the samples used for determinations increase.

The use of these tolerance percentages will permit lots of wheat that, as far as can be determined from one or two 100-gram samples, are near the grade limits to be placed in the higher rather than in the lower grades. The lowering of the present grade limits would not accomplish the same results since from whatever the limits established there would still be variation due to the fact that determinations on one or two samples as large as it is practical to use cannot be depended on to give the average of a large number of determinations.

SUMMARY OF CONCLUSIONS

Unequal division of the original sample by some Boerner samplers does not affect the grade of the grain unequally divided.

Taking samples for multiple determinations from different halves or fourths of the original sample has no advantage as far as accuracy is concerned over taking contiguous samples of the same size or one sample of the same size as the total of the smaller ones.

The indications are that samples for percentage determinations of 100 grams in size give significantly greater accuracy than samples of smaller size.

Further reduction of variability of determinations may be secured in approximately one-half of the cases by the use of samples 200 grams in size, but on account of the labor necessary in making separations on this size of sample it cannot be considered for use except for corn and in exceptional cases in making foreign material determinations on oats.

Even with the utmost care in making determinations on single or duplicate samples of the largest practical size, variability still occurs and the element of chance enters to a considerable extent into the grading of lots of grain which come near the grade limits.

To eliminate chance as far as possible in the grading of grain, a system of tolerances is proposed for heat damage and foreign material, based on the variability secured from determinations on a considerable number of samples of various weights taken from wheat containing approximately the grade limits of damage or of foreign material other than cereal grains.

Tolerance percentages of 30%, 20%, 10%, 10% and 5% below the present grade limits are suggested, respectively, for heat damage determinations in wheat containing approximately 0.1%, 0.2%, 0.5%, 1.0% and 3.0% of this kind of damage when samples 100 grams in size are employed.

When 50 gram samples are used tolerances of 35% for wheat containing 0.1% heat damage and 25%, 15%, 10% and 5% below the present grade limits respectively for wheat containing 0.2, 0.5, 1.0 and 3.0% are indicated.

The use of tolerance percentages such as the ones suggested justifies the placing of lots of wheat samples which vary below the grade limit by the amount of the tolerance in the grade above. This should result in more equitable grading than is possible where no tolerance is used in connection with the grading of wheat near the grade limits.

The use of the tolerance percentages suggested does not have the same effect as lowering the grade limits since there would be variability on either side of any new grade limits established necessitating still the use of tolerance percentages to promote more equitable grading.

LITERATURE CITED

1. FRANK, W. L. and CAMPBELL, R. L. Sources of error in sampling grain. Unpublished data. Grain Inspection Department, Sherman, Texas, 1922.

2. PHILLIPS, O. F. General Field Headquarters No. 58. Inspection Technique. 1922.
3. Association of Official Seed Analysts of North America. Rules for Seed Testing. 1917.
4. DAVENPORT, C. B. Statistical Methods. John Wiley & Sons, New York.
5. PEARL, RAYMOND and MINER, JOHN RICE. A table for estimating the probable significance of statistical constants. Me. Agr. Expt. Sta. Bull. 226. 1914.
6. WOOD, T. B. and STRATTON, F. J. M. The interpretation of experimental results. *In* Jour. Agr. Sci. 3: 417-440. 1910.
7. Official Seed Inspection. Wis. State Dept. of Agr. Bull. 46. 1922.

STUDIES IN THE ERADICATION OF WILD MORNING-GLORY[1]

GEO. STEWART and D. W. PITTMAN[2]

"Wild morning glory" (*Convolvulus sp.*) is widely known in the United States and many parts of the Old World as a bad weed. Spots appeared in Utah more than a generation ago. No serious attention was paid to the weed before 1900, except in one or two localities where it had early become troublesome. By 1921, it had become so serious in several counties—notably Sanpete, Millard, Juab, and Davis—as to attract widespread attention. Agronomists believed that it could be controlled by vigorous cultivation, but many farmers and several farmers' organizations insisted that this was inadequate. Meanwhile, a wave of sentiment for spraying with sodium arsenite swept over the most populous parts of the state.

PREVIOUS WORK

Examination of the literature showed results of attempts to control the weed to be considerably less conclusive than had been thought. A few tests of an experimental nature had been made, but for one reason or another these were by no means "clinching," at least for the Great Basin. Climatic differences had already been shown to affect the value of spray treatment to a confusing degree.

Cox (1)[3] had reviewed the situation with reference to morning glory control. He described a number of plants that go under the common name of bindweed, the worst of which are hedge bindweed (*C. sepium*) and field bindweed (*C. arvensis*), the two species of wild morning glory common in Utah. The conclusion was reached that top growth must be kept cut down, in order to starve the roots and rootstocks. Sowing infested land to alfalfa was suggested. The use of chemicals was not thought to be successful.

[1]Contribution from the Department of Agronomy, Utah Agricultural Experiment Station, Logan, Utah. Received for publication May 24, 1924.
[2]Agronomist and Associate Agronomist, respectively.
[3]Reference by number is to "Literature Cited", p. 518.

In one test at Davis, California, for the two years 1909–1911, Bioletti (2) found at a depth of 14 feet roots capable of producing new shoots. Tillage of the surface three feet of soil did not affect materially the vigor of the plant. Various tests on about 10 acres of uncropped land, however, showed that if the tops were cut back every five days during the season the roots lost about 70 percent of their weight and produced little top growth the next season. The labor cost of such tillage for the season was estimated to be $9.00 an acre.

Spraying had also been tried in California. Gray (3) conducted spray experiments from 1915 to 1919, along the coast where the air was humid and foggy. His spray consisted of 10 pounds of granulated caustic soda (98 percent) and 20 pounds of white arsenic (As_2O_3, 99 percent) in 5 gallons of water, diluted at the rate of one gallon of the stock solution in 100 gallons of water. Thoro spraying at blooming time killed 85 to 90 percent of the roots to a depth of 4 feet. The fields seemed free of the weeds for eight to twelve months, after which new shoots appeared. Gray believed that annual fall spraying (October preferred) would eventually eradicate the weed. Later, however, he found (4) that spray killed roots only where the air was so saturated with moisture as to allow time for the absorption of the poison before evaporation of the spray droplets took place.

In a somewhat more extended study of the effects of various chemicals on morning glory, Gray (5) applied several chemicals to the soil in an effort to kill the weeds by root absorption. This method failed to kill the weed at reasonable expense. It was also found that the concentration necessary to destroy the roots damaged the soil for the growing of crop plants.

Pammell and King (6) sprayed thirty-one different weeds and cultivated plants with copper sulfate, sulfuric acid, sodium chloride, carbolic acid, slaked lime, formaldehyde, corrosive sublimate, and other chemicals. Top growth was killed by all of them, but iron sulfate, at the rate of 2 pounds to the gallon of water and 50 gallons of solution to the acre, was recommended. An occasional change in the strength of spray and deep plowing were suggested as likely methods of control.

In Oregon (7), spraying mustard and pigweed with 20 percent solutions of iron sulfate retarded the growth of these weeds, but had no effect on morning glory. Solutions at 22, 24, 26, 28, 30 and 35 percent concentrations made no perceptible progress toward eradicating morning glory.

Meanwhile sodium arsenite (Na_3AsO_3) and various patented "weed killers," in which sodium arsenite practically always is a constituent, had come into favor as means of killing down weed growth on waste land, roadways, and in special phases of agricultural production (such as the growing of pine-apples in Hawaii) when spray could be applied between the rows. Much spraying was done between 1916 and 1921, in Utah, especially on vacant building lots in and around Salt Lake City. Top growth could be killed readily and the method was used as a fire-prevention measure. In several cases, weedy roadways, canal banks, and railroad right-of-ways were sprayed and the top growth killed. A heavy bed of morning glory south of Salt Lake City was treated a few times, but with only temporary success.

During the last few months, in fact after the test reported here was complete, two new publications dealing with the eradication of morning glory have appeared. Barnum (8) has summarized the California data already cited and reiterates that cutting for one season will so reduce the roots by starvation that they can be completely eradicated by a reasonable amount of cultivation and hoeing. His treatise dealt with the small-leaved species (*C. arvensis*).

Call and Getty (9), discussing the prevalence of bindweed (*C. arvensis*) in Kansas, state that it is limited to from one to fifty farms in each county and usually to only a few square rods on each farm, but that in some parts tracts of 80 to 160 acres are occupied. Applications of 20 to 28 tons of salt to the acre killed most of the weeds, but left the land useless for several years. At Fort Hays, Kansas, two or three plowings, an occasional disking and frequent harrowing with a spring-tooth harrow, amounting to 20 treatments in all, killed 85 to 99 percent of the plants. Eradication was completed in the second season by about a dozen treatments. No mention is made of the possibility of a cultivated crop in place of fallow and tillage during the second season. Close hog-pasturing and a smother crop of alfalfa, sorghum, or Sudangrass are recommended when conditions warrant their use.

OCCURRENCE OF MORNING GLORY IN UTAH

In 1923, county agents and ex-agents estimated the areas of morning glory in Utah to be as shown in Table 1.

EXPERIMENTAL WORK

During the winter of 1920–1921, several conferences were held at which attempts were made to analyze the problem. It was deemed

TABLE 1.—*Number of areas and total acreage of morning glory in the counties of Utah. (Estimated by County Agents, 1923)*

County	No. of areas	Total acreage	County	No. of areas	Total acreage
Beaver......	60	50	Millard......	110	1,000
Boxelder.....	—	75	Morgan......	47	33
Cache.......	300	150	Salt Lake.....	200	150
Carbon......	2	1	Sanpete......	750	10,000
Davis.......	180	200	Summit......	50	25
Emery.......	6	2	Tooele.......	150	350
Iron.........	50	12	Utah........	500	100
Juab........	60	400	Weber.......	—	200

advisable to investigate somewhat thoroly the methods that were so frequently advocated. About this time a ten-acre tract of land was added to the central experimental farm at Logan, Utah. On the north side of this land there was an unbroken bed of large-leaved wild morning glory (*C. sepium*) about two acres in extent. In addition there were several small "spots" varying in size from a few square feet to several rods. On this land the experimental plats were laid off.

The field on which the test was conducted is about one-half mile northwest of the central experimental farm at North Logan. The field extended 42½ rods from east to west. Along the north fence, extending the entire 42½ rods, a solid bed of the large-leaved morning glory (*Convolvulus sepium*) reached southward approximately 7 rods at the east fence line and 10 rods at the west. This bed was laid off into 21 plats, each two rods wide from east to west, and 10 rods north to south. Another area near the middle of the west side about 4 rods by 8 rods in extent, was made into 4 hog pastures each 2 rods by 4 rods in size.

The field was sown to sugar-beets about May 1, 1921. When the beets first came up, the stand was good with morning glory just becoming visible. By the end of May, the morning glory had completely hidden the beets. Careful examination showed the infestation to be essentially a solid occupation. There were no bare spots and but few places where the stand was thin.

On June 15th, a beet cultivator with the duck-foot blades was run over the land at a depth of about 3 inches. This cultivation was repeated several times until all surface growth was entirely removed.

PLAN OF TREATMENT

The 21 large plats were measured carefully and pegs placed at the corners. By July 1 there was sufficient top growth to cover the ground, the branches being about 6 to 12 inches long and growing rapidly. Treatments began on July 1 and continued to October 1. The method and frequency of treatment are shown in Table 2.

Plats 1 to 5 and 11 to 15, inclusive, were sprayed with sodium

arsenite (Na_3AsO_3) obtained in a liquid form. Directions accompanying the arsenite suggested a dilution of one part of the chemical in 100 parts of water. This was taken as ordinary strength and half strength or double strength made up proportionately. The tops were allowed to make sufficient growth for the land to appear green before

TABLE 2.—*Treatment of spray and tillage plats.*

Plat	Method	Frequency
1 and 11	Spray, ordinary strength	Frequent (as soon as surface seemed green)
2 and 12	" " "	Half as often
3 and 13	" one-half strength	Frequent
4 and 14	" double strength	Frequent
5 and 15	" ordinary strength	Delayed till bloom
6 and 16	Tillage, shallow	Frequent (as often as shoots appeared)
7 and 17	" "	Half as often
8 and 18	" deep plowing	Once followed by shallow cultivation
9 and 19	" shallow plowing	Whenever shoots appear
10 and 20	Smother, Russian sunflowers	Cultivated once and hoed once when sunflowers were 4 feet tall.
21	Check plot—untreated except one spray treatment on August 10th, to prevent seeding.	

the spray was applied. The time required for this to happen was about a week in the early part of the season, gradually increasing to two weeks as the season advanced.

Shallow cultivation treatments were at first applied by means of a beet cultivator with blades. Later, a sled knife was made by fastening a steel blade beneath a solid frame in such a way that it cut about 3 inches below the surface. As soon as any growth appeared above the surface, cultivation was applied on the frequently treated plats; the infrequently treated plats were cultivated each alternate time. Growth appeared in about five days during July and in about ten days during September.

Plowed plats received treatment that varied slightly from this plan. The two plats given the deep-plowing treatment were plowed July 1 about 15 inches deep and thereafter cultivated shallow to keep down top growth. The plats for shallow plowing were plowed to the depth of about 6 inches whenever growth began to appear. The treatment was required every ten days at first and every fifteen days later in the season. No tillage except plowing was applied to these plats. Smother plats were sown on July 1st to Mammoth Russian sunflowers in rows 20 inches apart with plants every 3 or 4 inches in the row. When the sunflowers were about 4 feet tall, the rows were cultivated once and hoed thoroly. Thereafter no treatment whatever was applied during the season until the land was fall-plowed about November 15th. The sunflowers grew about ten feet in height and shaded the ground thoroly except along the edges

where the light came in for a few feet. No morning glory grew except where this light reached.

PLAT DATA OBTAINED

On October 1, a careful digging test was made to find the relative abundance of rootstocks, it being thought that this would at least indicate the general effect of the treatments. The holes were exactly two feet square (four square feet in area). As the dirt was removed the rootstocks were picked out by hand and saved. Digging was continued until no more roots were found, which in this case was at a depth of about thirty inches, where a water-table had stopped penetration. Care was taken to keep the holes the same size so as to make the data comparative. As soon as dug the roots were taken to the laboratory, washed clean, and weighed. After being thoroly air-dried the dry-weights were obtained. The data thus obtained are shown in Table 3.

During the process of digging it was observed that rootstocks taken from frequently tilled plats were slender, watery, and brownish in color whereas those taken from spray plats and from the check plats were plump and white. On the sunflower plats the ground seemed full of decaying strand-like plant tissue that appeared to be dead rootstocks.

TABLE 3.—*Fresh weight and air-dry weight of rootstocks from spray and tillage plats, October 1, 1921.*

Plat number	Treatment applied	Rootstocks Fresh weight grams	Rootstocks Air-dry weight grams
1	Spray—ordinary—frequent	180	24.2
2	Spray—ordinary—½ frequent	551	106.8
3	Spray—½ ordinary—frequent	82	10.3
4	Spray—2 ordinary—frequent	106	14.1
5	Spray—delayed till bloom	462	78.2
6	Cultivation—shallow—frequent	19	0.8
7	Cultivation—shallow—½ frequent	21	2.3[a]
8	Deep plowing—then shallow tillage	18	2.3
9	Shallow plowing—frequent	49	2.3
10	Sunflowers—one hoeing	17	3.6
11	Spray—ordinary—frequent	236	40.2
12	Spray—ordinary—½ frequent	371	61.3
13	Spray—½ ordinary—frequent	237	36.1
14	Spray—2 ordinary—frequent	66	7.2
15	Spray—delayed till bloom	538	106.9
16	Cultivation—shallow—frequent	36	2.2
17	Cultivation—shallow—½ frequent	465	74.5[a]
18	Deep plowing—then shallow tillage	9	1.1
19	Shallow plowing—frequent	9	1.1
20	Sunflowers—one hoeing	7	1.8
21	Check—no tillage—one spraying to prevent seeding	503	119.1

[a]Plats 7 and 17, tho duplicate for treatment (infrequent shallow tillage), do not agree in results. All other duplicates do, at least in a general way.

Next spring after growth had time to get well started, another set of small sample plats was laid off, each two feet square, that is four square feet in area. This time the top growth was shaved off at the surface and the shoots counted. The fresh weight was taken immediately and the dry weight after the material had become thoroly air-dry. The small sample plats were now taken in what seemed to be an average area of the field plat. Rootstock sampling in the fall could not allow for this because no top growth showed at the time. The closeness, however, with which spring growth agrees with the dry weight of rootstocks is striking. It was also decidedly apparent that untreated plats gave a more vigorous and rapid spring growth. The shoots on the check plat started several days earlier, grew faster, and were about three times as long and about eight times as heavy on June 8th, as were the shoots from the frequently tilled plats. The data are shown in table 4.

TABLE 4.—*Number of plant shoots, green weight, and dry weight of top growth on spray and tillage plats, June 8, 1922.*

Plat number	Treatment applied	No. of shoots	Weight of tops Fresh grams	Weight of tops Air-dry grams
1	Spray—ordinary—frequent	89	79	14.5
2	Spray—ordinary—½ frequent	212	294	46.5
3	Spray—½ ordinary—frequent	121	110	20.5
4	Spray—2 ordinary—frequent	59	28	5.0
5	Spray—delayed till bloom	291	318	60.
6	Cultivation—shallow—frequent	1	1.5	0.5
7	Cultivation—shallow—½ frequent	51[a]	26	4.0[a]
8	Deep plowing—then shallow tillage	29	13	2.0
9	Shallow plowing—frequent	15	9	1.0
10	Sunflowers—one hoeing	33	28	5.0
11	Spray—ordinary—frequent	127	80	15.0
12	Spray—ordinary—½ frequent	266	234	44.0
13	Spray—½ ordinary—frequent	185	135	27.5
14	Spray—2 ordinary—frequent	80	56	10.5
15	Spray—delayed till bloom	279	285	47.5
16	Cultivation—shallow—frequent	13	7	0.5
17	Cultivation—shallow—½ frequent	134[a]	98	18.5[a]
18	Deep plowing—then shallow tillage	23	9	1.0
19	Shallow plowing—frequent	10	6	0.5
20	Sunflowers—one hoeing	37	42	7.0
21	Check—no tillage—one spraying to prevent seeding	169	668	98.0

[a]The lack of agreement between plats 7 and 17 is still noticeable.

Sugar beets were again sown on the land in 1922. The plats were shortened two rods on the south and this strip clean tilled with a beet cultivator thruout the season. It was decided to grow the beets on all plats possible. Plats on which there remained a heavy stand of weeds were sprayed or planted to corn as a smother crop. The treatments and the yield at harvest are shown in Table 5.

TABLE 5.—*The cropping treatment and weed control treatment for the 21 plats. The acre yield is also given for each treatment (1922).*

Plat	Cropping treatment	Weed control treatment	Acre yield tons
1	Fallow	Frequent shallow cultivation	
11	Sugar-beets	Two hoeings	7.12
2–12	Sugar-beets—spray	1:100, frequent	
3–13	Sugar-beets—spray	1:100, frequent	
4–14	Sugar-beets	Two hoeings	8.34
5–15	Beets smothered, cleaned and sown to corn for smother crop		
6–16	Sugar-beets—normal	Ordinary care	11.93
7–17	" " "	" "	11.32
8–18	" " "	" "	12.83
9–19	" " "	" "	13.11
10–20	" " "	" "	8.05
21	Fallow—subdivided	Various chemicals and smother	

Because of the fact that it was in front of the field entrance and also isolated by spray plats and a fence, it was decided to fallow plat 1, and to hoe weeds from plat 11, its duplicate. It did not seem possible to grow beets on plats 2, 12, 3, 13, 5, and 15 on account of the dense weed stand yet remaining. Plats 2, 12, 3, and 13 were sprayed with a double strength spray frequently enough to kill down the top growth of morning glory. This killed all the beets also except about a dozen on each plat. The smother crop of corn on plats 5 and 15 was drilled in rows 24 inches apart, with the seed not over an inch in the drills. Because the corn did not grow as rapidly as had the sunflowers the season before, it was never effective in checking the weed growth. Plats 6 to 10 and 16 to 20 all grew fair to good crops of beets with no care except normal cultivation including two light hoeings. Plats 10, 17, and 20, however, required vigorous weeding to keep the morning glory in check. The other plats were given merely ordinary care such as beets receive on clean ground, with only a little more care in hoeing so as not to miss any shoots of morning glory. The beets were not delayed or disturbed in any way on the ten plats that had been given tillage in 1921, except in the cases of 10, 17, and 20 where vigorous hoeing reduced the stand and caused excessive work. The fact that plat 7 was nearly free from weeds has been already noted. It yielded 12.54 tons an acre as compared with 10.10 tons for plat 17 which was rather weedy.

In 1923, the entire experimental area was again sown to beets. These were grown successfully in all cases, but plats 2, 3, 5, 12, 13, and 15 required vigorous weedings. Plats 4, 10, 11, 14, 17, and 20 required some extra attention to get out all of the shoots of morning glory, whereas plats 6, 7, 8, 9, 16, 18, and 19 were cultivated as if on land that had always been clean. Of course, a sharp lookout was

maintained for morning glory top growth but only a few shoots were found and none at all—not even a single one—on plats 6, 9, 16, and 19. At the north end of the plats, along the fence line, some morning glory plants still persisted, due principally to inability to make the 1921 cultivation effective close to the fence. As the season advanced it became apparent that the stand of beets was decreased on the plats that required vigorous hoeing to hold the morning glory in check. Not long before harvest careful counts were made on six of the rows, which ran the entire length of the field from east to west across all of the 20 plats. The beets were no larger on the plats that had been hoed more to keep down the weeds. The stand of beets will be a fair check on yield in 1923, the second year after the treatment was applied.

TABLE 6.—*Number of sugar-beets harvested on the same six rows in each plat (1923)*

Original treatment (1921)	Plat	Number of beets	Plat	Number of beets	Total No. of beets
Spray—1:200, frequent........	1	a	11	109	218[a]
Spray—1:200, ½ frequent.....	2	70	12	72	142
Spray—1:400, frequent........	3	110	13	95	205
Spray—1:100, frequent........	4	143	14	97	240
Spray—1:200, delayed till bloom	5	95	15	93	188
Cultivation—shallow, frequent..	6	147	16	118	265
Cultivation—shallow ½ frequent	7	141	17	104	245
Deep plowing—then shallow cultivation................	8	139	18	143	282
Shallow plowing—frequent.....	9	143	19	149	292
Smother—Russian sunflowers...	10	116	20	106	222

[a]Plat 1, clean cultivated; total for treatment obtained by doubling the number on plat 11.

RESULTS OF PASTURING BY HOGS

The four plats (24, 25, 26, and 27) fenced for hogs had made considerable growth. Since the morning glory was not heavy, there was about a half stand of sugar beets that were good sized by July 27th, when three hogs were turned into plat 24. By August 13, plat 24 was well rooted up and entirely bare. The gate between plats 24 and 25 was then opened and the hogs allowed access to both plats; as the hogs were growing and needed more feed, they more quickly cleaned plat 25, tho there was the additional growth of seventeen days on it. On August 22, they broke into plat 26, and were allowed to remain there, as plats 24 and 25 were bare and the rootstocks seemed to be well rooted out. On September 3, the hogs were let into plat 27 and allowed access to all four plats. The growth on plat 27 lasted only a few days but the hogs were kept in the pasture till November 1, being kept alive by small amounts of barley grain. They became extremely thin and seemed to be ravenously hungry all

the time. They rooted everywhere and seemed to have made about as thoro a job of rooting as possible. On October 1, when the digging for rootstocks was done on the large plats, similar diggings were made on the four hog-pasture plats. The results are shown in Table 7.

During the next season hogs were again pastured on the plats. There was considerable reduction in the stand as compared to the check plat; but the hogs seemed unable to reduce the rootstocks beyond a point at which about one-third or one-fourth of a full stand remained. During 1922, the growth of morning glory just about maintained itself, being as thick in the fall as in the spring.

TABLE 7.—*The weight of fresh and air-dry rootstocks found in 4 square feet on hog-pastured plats (October 1, 1921).*

Plat	Treatment	Weight of rootstocks Fresh grams	Air-dry grams
24	Hogs turned in July 27	40	8.1
25	Hogs turned in August 13	51	9.9
26	Hogs turned in August 22	34	9.4
27	Hogs turned in September 3	43	11.5

CHEMICAL SPRAYS AND OTHER TREATMENTS

Spray of a much-advertized patent weed killer, of crude oil, of kerosene, of salt brine, and of gasoline, and building paper for shade were applied to small areas of morning glory on another piece of land—on the south edge of a new six-acre field, about 40 rods south of the Greenville farm. The sprays were applied several times thruout the season; but had no important effect, except in the cases of gasoline and of weed-killer which weakened the weeds. The weed-killer had with it printed directions which said to scalp the surface of top growth before applying. A plat was divided and half of it scalped before applying the spray according to directions; on the other half, the spray was applied to the growing plants. Rootstocks were dug on October 1, at the same time as for other treatments.

TABLE 8.—*Weight of fresh and air-dry rootstocks on 4 square feet of chemical spray and paper-covered plats (October 1, 1921).*

Plat	Treatment	Weight of rootstocks Fresh grams	Air-dry grams
22	Weed-killer—scalped	132	18.5
23	Weed-killer—growth sprayed	14	2.2
28	Spray—crude oil	819	125.0
29	Spray—kerosene	281	43.6
30	Spray—salt brine	194	27.2
31	Spray—gasoline	108	14.9
32	Shade—building paper	99	11.5

During the second season, plat 21 (the check plat) was divided into several small plats, one-half of each being hoed clean, or "scalped,"

just ahead of treatment with kerosene, gasoline, oil, salt brine or weed killer, respectively. One part was covered with about four or five feet of well rotted straw. This made a much more compact mass than would ordinary straw. The edges were hoed around to prevent plants thus exposed to light from feeding the rootstocks under the straw.

There has been no appreciable effect of any sort due to spraying with these chemicals, except the "weed killer," which was found by chemical analysis to contain large quantities of sodium arsenite. This killed top growth and affected the plant generally in a manner almost identical to the sodium arsenite spray. The gasoline also killed the top growth each time it was applied. The straw, applied in midsummer, seemed to be effective until about midsummer of the next season, when shoots came thru and quickly made an almost complete covering of green leaves in about two weeks.

CORROBORATIVE TRIALS

The weed studied in this experiment, hedge bindweed (*Convolvulus sepium*), is an easier weed to eradicate than is field bindweed (*Convolvulus arvensis*). It may also be urged that the water-table was too near the surface to permit roots or root-stocks to develop as deeply in the soil as they would on well-drained land.

In 1920, the experiment station bought another tract of land just north of the Greenville farm. The field had in it one large spot and several small ones of the small-leaved morning glory, field bindweed (*Convolvulus arvensis*). No effort was made to determine the depth of root penetration on this land. Since, however, the water-table is about 100 to 120 feet below the surface (an artesian well was driven about 15 rods away in 1922), there was nothing to prevent full development of the root-system. In this field, neither of the objections raised against the plat tests holds. Almost perfect eradication of the large spot of bindweeds was accomplished in one season.

During 1920, the land was sown to sugar beets and grain, and farmed in the usual manner, but on the larger spot of morning glory the yield was almost nil. In 1921 this area, about one-fourth acre in size, was summer-fallowed and cultivated with a beet cultivator as often as new growth started. No record was kept as to the number or frequency of cultivation, but it was applied approximately once a week thruout the earlier part of the year, becoming less and less frequent towards autumn. That fall, a seedbed was prepared and the land seeded to the rod-row winter-wheat nursery for plant-breeding trials. The rows were one foot apart and hand hoed during

1922. Some morning glory top growth appeared during June, but this was promptly cut off 3 or 4 inches below the surface. At intervals of a few days the grain rows were gone over and an occasional shoot of morning glory found and cut off. During 1923 two plants only were found and these seemed to be seedling plants, possibly from seed that had lain dormant in the land since 1919 or 1920.

DISCUSSION

At first it was difficult to find a method of measuring progress toward eradication. It was not known that digging for rootstocks would serve adequately, but trial seemed to indicate that such was the case. On fallow land, the possibility of digging in a nearly bare spot or in the heart of a heavy stand had to be considered. It was found that by digging tentatively here and there about the plat a representative spot could be approximated. Actual stand during the next season was used as a check on the amount of rootstocks. As may be seen by comparing the data in Tables 3 and 4 there is an almost unexpected agreement between the weight of rootstocks gathered in October and the top growth the following June.

Comparison of the top growth, both as to number of shoots and total weight produced, shows the sprays to be much less effective than tillage—at least of a comparable sort, that is, when frequent is compared with frequent, and intense with intense. On the plats which were sown to a smother crop of Russian sunflowers, there remained only a few rootstocks, but these few seemed plump and unexhausted as compared to thin strand-like ones on the frequently tilled plats. A much heavier top growth during the succeeding spring from these plats than from those frequently tilled indicated that the appearance of the rootstocks was a fair indication of the stage of exhaustion.

The smaller amount of rootstocks and the less thrifty top growth on the plats which received frequent shallow tillage seem to indicate that if there be any appreciable difference between plowing and surface cutting, the advantage is with the surface cutting. Shallow plowing seemed to be equally as effective as deep plowing, if not slightly more so. Everything seemed to indicate that eradication was hastened by that treatment which permitted the most rapid growth and consequently the most rapid destruction of tops.

The acre yields of sugar-beets obtained during the second and the third seasons, the proportionate stand of beets in the third season, and the amount of hoeing required to save the beets all show the spray treatment to be much less effective than tillage or even than a

smother crop of Russian sunflowers. The large proportion of the stand of morning glory which remained even after two seasons of spraying leads the writers to doubt that eradication can ever be accomplished by this method, at least in a reasonable time.

On the hog-pastured plats, there was a reduction to a point at which only about 8 or 10 percent of the rootstocks remained, but no apparent decrease beyond this.

A strict analysis of the experimental data obtained from smother crops does not permit them to be applied to another smother crop than Russian sunflowers. Kansas experience with sorghum and Sudan-grass suggested that corn planted close in drilled rows might be used. Alfalfa was also suggested for Kansas where the areas were too large to permit applying the frequent shallow-tillage treatment.

Shoots came thru four feet of straw and developed many green leaves. They also showed unexpected ability to spread horizontally but were not allowed to do this, the outside edges of the straw heap being kept clean by frequent hoeing. The same general result was obtained with building paper. The edges were kept clean by hoeing but the paper was penetrated here and there in various ways. Irrigation water seemed especially likely to weaken the paper. Tar paper was not used in this case but heavy building paper was given every chance possible save that it was allowed to come in contact with irrigation water. It was felt that this was a condition that must be met on most of Utah's infested land, as irrigation was likely to be necessary to maintain growth.

LITERATURE CITED

1. Cox, H. R. The eradication of bindweed or wild morning glory. U. S. D. A. Farmers' Bul. 368 (1908), pp. 19.
2. Bioletti, F. T. The extermination of wild morning glory. Calif. Agr. Exp. Sta. Cir. 69 (1911) p. 12.
3. Gray, L. P., Spraying for the control of wild morning glory within the fog belt. Calif. Agr. Exp. Sta. Cir. 168 (1917) p. 7.
4. Chemical control of the morning glory etc. Calif. Agr. Exp. Sta. Rpt. 70, p. 44–52.
5. Gray, L. P. Test of chemical means for the control of weeds. Univ. Cal. Pub. Agr. Sci. (1919) No. 2, p. 67–97.
6. Pammell, L. H., and King, C. M. Notes on eradication of weeds with experiments. Iowa Agr. Exp. Sta. Bul. 105 (1908) pp. 265–300.
7. Withycombe, R. Report of the department of Agronomy. Oregon Agr. Exp. Sta. Rpt. East. Oreg. Sta. 1911–12, pp. 6–32.
8. Barnum, Clyde C. The control of wild morning glory. Calif. Agr. Exp. Sta. Cir. 256 (1923) pp. 1–22.
9. Call, L. E., and Getty, R. E. Eradication of bindweed. Kan. Agr. Exp. Sta. Cir. 101 (1923) pp. 1–18.

YIELDS OF WHEAT FOLLOWING POTATOES AND THE RELATION OF NITRATES IN THE SOIL TO THESE[1]

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INTRODUCTION

Among farmers the impression is general that the potato crop is a good one after which to sow wheat. The explanation of this belief has been for years, and still is, a topic for lively debate among wheat growers. In the consideration of this or any similar question, it is in order first to inquire if the notion is true; and if it be true, then secondly, to ask to what cause it may be due. So far as the writers are aware, this feeling among farmers is based, not on experimental evidence, but rather, upon the accumulated observation and experience of multitudes of farmers extending back through the years. Usually when an outstanding yield of wheat is reported, it is found to have been grown after potatoes. The most noteworthy instance of this kind of which the writers have knowledge is one reported by the United States Bureau of Crop Estimates (5). According to this Bureau, the highest yield of wheat, so far as it has ever been able to ascertain, is one obtained in 1895 in Island County, Washington. It was grown in an 18-acre field and the average yield per acre by weight was 117.2 bushels. The wheat, according to this report, had been preceded by three crops of potatoes.

Moreover, there is some experimental evidence which indicates that the farmers are correct in their opinion. For example, on the farm of the Ohio Agricultural Experiment Station, some 600 plots have been used in the production of wheat for more than a quarter of a century. These plots embrace many different rotations, and among them is one in which wheat follows potatoes, the rotation being potatoes, wheat and clover. In this series of plots, the more liberally fertilized ones have a higher quarter-of-a-century average yield of wheat than have those included in any other rotation on the farm. Moreover, it is believed by former Director Chas. E. Thorne that the most productive plot in the series, Plot 14, has the highest long-time average yield of wheat recorded anywhere in the world.

EXPERIMENTAL WORK

OBJECT

The purpose of this paper is to discuss two points: first, the valid-

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ity of the belief that wheat following potatoes yields higher than does wheat following most of the other more common farm crops; and second, to offer a possible explanation for the behavior of wheat following potatoes.

MATERIALS AND METHODS

Wheat yields and the nitrate content of certain soils constitute the data upon which the major part of this paper is based. All of the wheat crops and most of the soil samples were obtained from the field plots (one-tenth acre in size) on the Central Experiment farm at Wooster; the cultural, fertility and rotation plots, particularly the latter, being the ones from which most of the material was taken. Some soil samples were obtained in the summer of 1923 from a few general farm fields in the Creston tobacco region, located about 12 miles north of Wooster.

The nitrate determinations were made on composite samples of soil consisting of four borings, each taken to a depth of approximately seven inches. After sifting through a quarter-inch mesh sieve, a 200-gram sample was shaken with 1,000 cc. of distilled water from 1½ to 4 hours. Nitrate determinations in duplicate were made upon the filtrate, using the modified Devarda reduction method. The results of the nitrate determinations are recorded in parts per million of dry soil.

THE YIELD OF WHEAT FOLLOWING POTATOES

To answer the question as to whether wheat following potatoes really does yield higher than wheat following most of the other more common farm crops, one method and perhaps the best available one is to grow wheat after various crops, including potatoes, and under conditions otherwise uniform in all particulars as far as possible.

The rotation work of the Ohio Agricultural Experiment Station affords an opportunity to make a comparison under such conditions. In this work, wheat is being grown after corn, oats, wheat, clover, soybeans, and potatoes. All of these crops are produced every year in the same field, on uniform soil equally drained, manured, fertilized, and limed. These tests embrace five classes of rotations (one-year or continuous, two-, three-, four-, and five-year) and a total of 28 individual rotations. Averaging all the yields of wheat after each crop, including the different classes of rotations, they rank in the following order:

Wheat after	corn	10	rotations	32.54 bu.
" "	soybeans	6	"	33.12 "
" "	oats	3	"	34.85 "

Wheat after	clover	3 rotations	35.69 bu.
" "	potatoes	5 "	36.43 "
" "	wheat	1 rotation	36.92 "

Strange to say, in these experiments covering eight years, the highest average yield of wheat has been obtained where wheat follows wheat. However, older work in continuous cropping of wheat has demonstrated that the yield, by this method, is not long maintained. Therefore, this yield may well be omitted from further consideration in this connection. Barring the continuous cropping test, the wheat following potatoes yielded higher than did that following any other crop. The records show that this is true also of each class of rotations except one, the four-year, in which case the yield of wheat following clover exceeded that following potatoes by 3.85 bushels. In this connection, it may be added that in each class of rotations the lowest yield of wheat was always found in a rotation where wheat followed corn.

The variation in yield of wheat as a result of its following different crops is quite marked in all classes of rotations. For example, in the five two-year rotations, the difference between the highest and lowest yield was 6.46 bushels, a gain of 21.7 percent in favor of the potatoes.

In the six three-year rotations, the difference between the highest and lowest yield was 6.75 bushels, a gain of 20.1 percent in favor of the potatoes.

In the eight four-year rotations, the highest yield of wheat came after clover, as has already been noted; but the second and third highest came after potatoes, the increase of the highest potato rotation over the lowest rotation of this class being 10.86 bushels, or a gain of 38.57 percent in favor of the potatoes.

In the eight five-year rotations, the difference between the highest and lowest yield was 10.81 bushels, or a gain of 37.43 percent in favor of the potatoes.

These experimental results are in line with the well defined opinion of farmers. They indicate that on the average, wheat following potatoes does yield a little better than does wheat following any of the other crops included in this discussion.

However, further analysis of the figures shows that the yield of wheat following potatoes is not always higher than it is following other crops. Only in certain seasons is this true. For example, in the eight years of this test the yield of wheat following potatoes ranked first four times in the two-year rotations; four times in the three-year rotations; two times in the four-year rotations and three times

in the five-year rotations. But an outstanding yield of wheat following potatoes happens often enough, and when it does occur the increase is great enough, so that the general average yield of wheat following potatoes exceeds that following any of the other crops included in this test. Since this is the case, the question arises as to why it is true and that query leads to a consideration of the second part of this paper.

CAUSE OF HIGH WHEAT YIELDS FOLLOWING POTATOES

This matter will be taken up in two sections: First, the influence of nitrates on wheat yields, and second, the source of nitrates.

Before presenting any results, attention is first called to a few significant facts which may be gleaned from the older fertility work of the Ohio Agricultural Experiment Station. This is done because these facts serve to form a background for a part of the discussion which is to follow.

INFLUENCE OF NITRATES ON WHEAT YIELDS

Compare, for example, the yields of wheat on Plots 11 and 17 in the five-year-rotation fertility work. (For treatment of these plots see Ohio Agr. Exp. Sta. Bulletin 336). The thirty-year average of Plot 17 is 24.36 bushels; of Plot 11, 28.73 bushels, a gain for the latter of 4.37 bushels or 17.9 precent. The greater yield of Plot 11 cannot be attributed to potassium because both plots receive the same amount of potassium chloride. It can hardly be due to phosphorus because Plot 11, the higher yielding one, receives in the course of each rotation period, 160 pounds less of acid phosphate than does Plot 17. Since nitrogen is the only other variable factor, the gain must, therefore, be due to it. Plot 11 receives twice as much of this element per rotation as Plot 17.

Further, compare Plots 8 and 11 in the same rotation. The thirty-year average yield of wheat of Plot 8 is 22.57 bushels; of Plot 11, 28.73 bushels, a difference of 6.16 bushels or a gain of 27.3 percent in favor of Plot 11. Both of these plots receive the same amount of potassium and phosphorus, but Plot 8 receives no nitrogen. The gain of Plot 11 over Plot 8 is, therefore, the direct result of the nitrogen added to the former.

Again, it is of interest to compare the difference between these two plots with the difference between the corresponding and similarly treated plots in the three-year potato rotation. In the latter, the twenty-nine year average wheat yield of Plot 8 is 36.16 bushels; of Plot 11, 37.92 bushels, a gain of 1.76 bushels or 4.9 percent. Be-

tween these two plots, therefore, the difference in yield of wheat is 4.40 bushels greater in the five-year rotation where wheat follows oats than it is in the three-year rotation where wheat follows potatoes.

Attention is directed to these long-time fertility experiments because they illustrate; first, the importance of nitrogen in wheat production; and second, the apparent independence of wheat from commercial nitrogen in a potato rotation. These results raise the question as to whether Plot 8 in the potato rotation does not obtain nitrogen from some source other than from commercial fertilizer used. Is there a greater residue of nitrates left in the soil after the removal of a crop of potatoes than there is after the removal of most any other farm crop?

To answer this question, a series of nitrate determinations was started in the fall of 1921 on six different plots, each of which had been in a different crop that summer, but all of which were seeded to wheat that fall. The complete rotations of which each one of these six plots forms a part are:

1. Corn, *oats*, wheat, clover.
2. Corn, *corn*, wheat, clover.

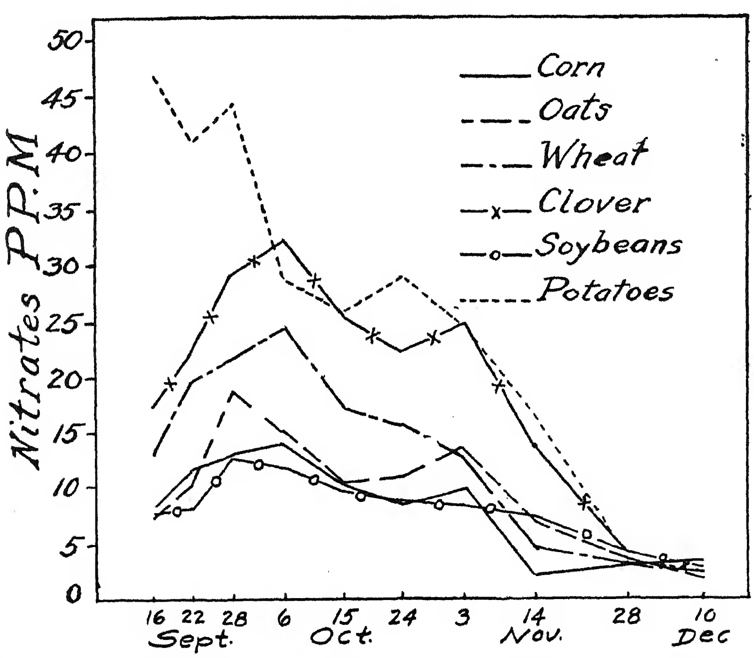

FIG. 1. Graphs of nitrates in corn, oat, wheat, clover, soybean, and potato plots, all of which were seeded to wheat in the fall of 1921.

3. Corn, *potatoes*, wheat clover.
4. Potatoes, *soybeans*, wheat, clover.
5. Corn, oats, *clover*, wheat.
6. Wheat, wheat, *wheat*, wheat.

In each rotation there are as many plots involved as there are crops included in the rotation, so that any given crop, except the continuous cropping wheat, is grown on a different plot each year. In this nitrate work, therefore, the soil samples, with one exception, have been taken from a different plot every year.

The dates of sampling and the quantity of nitrates found during the fall months of 1921 are shown in Figure I.

In these results, it will be noted that the potato plot ranks highest

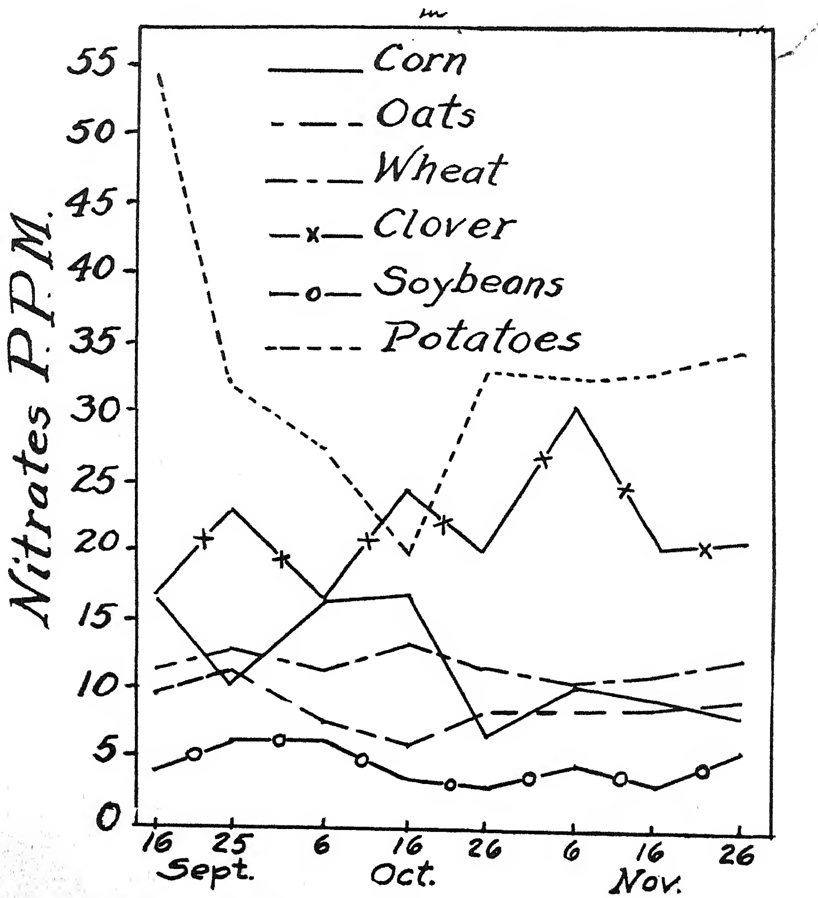

FIG. 3. Graphs of nitrates in corn, oat, wheat, clover, soybean, and potato plots, all of which were seeded to wheat in the fall of 1922.

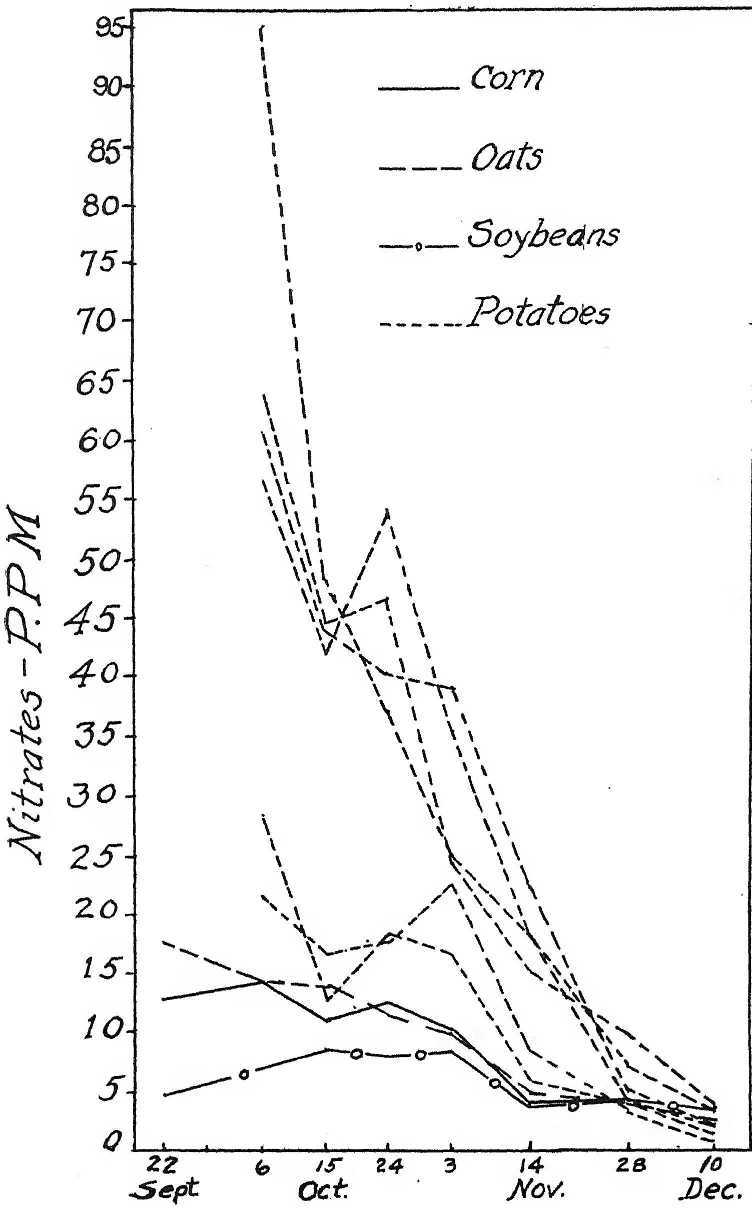

FIG. 2. Graphs of nitrates in six potato plots and in three wheat fields; one each following corn, oats, and soybeans.

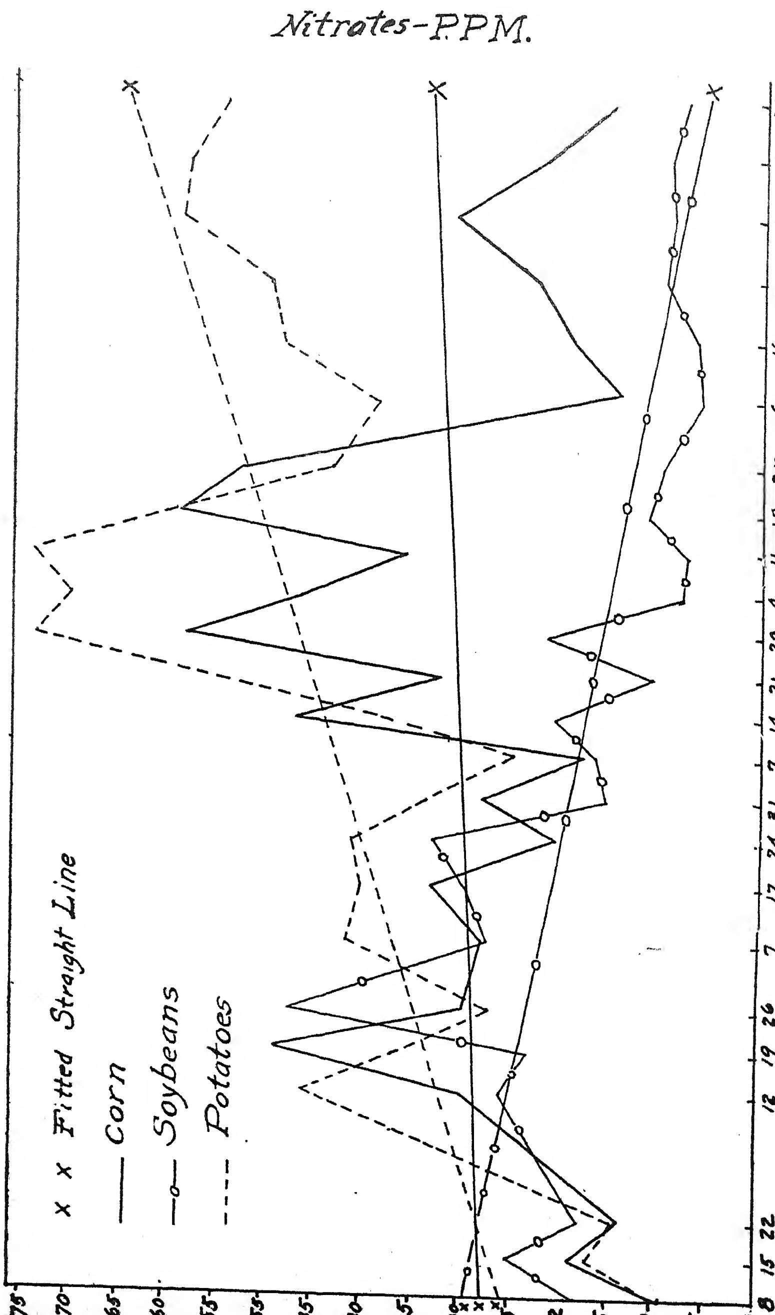

FIG. 4. Graphs of nitrates in corn, soybean, and potato plots during the season of 1922.

and the soybean plot lowest. Why a non-legume like potatoes should leave more nitrate nitrogen in the soil than a legume like soybeans is not altogether clear. It is not difficult to see why the clover plot should run relatively high because clover is a legume and, moreover, the land was plowed relatively early thus taking on for a time a fallow condition. The wheat ground also was plowed early, and thus it, too, benefitted from a short period of fallowing.

When the relatively high nitrate content of the potato plot was observed to persist from week to week, it was thought advisable to include in the test additional potato plots lest this one should prove to be unrepresentative of its class.

Accordingly six additional plots were sampled on October 6 and the

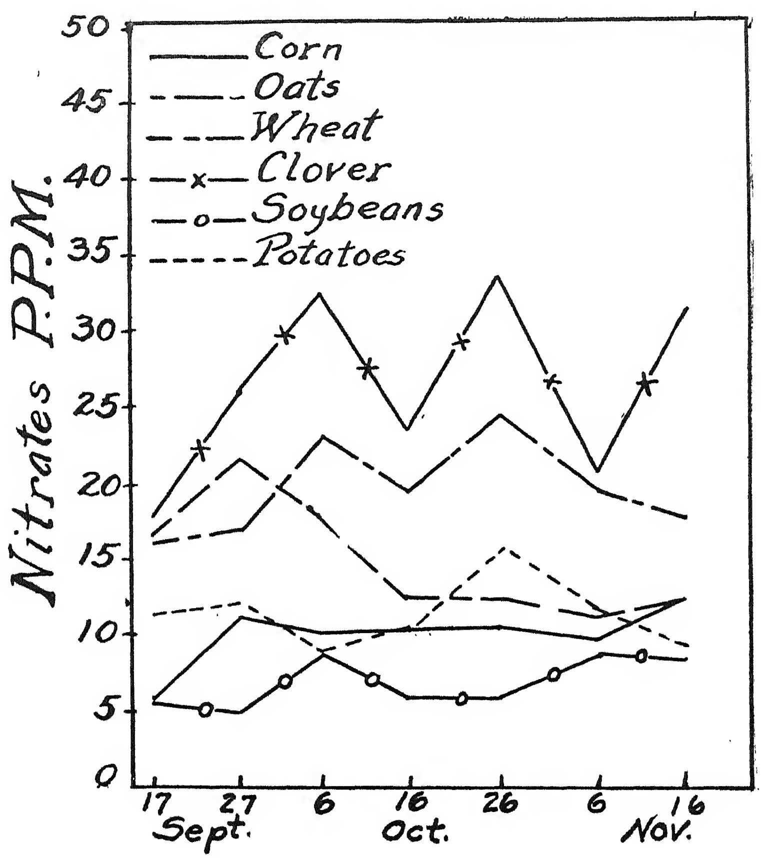

FIG. 5. Graphs of nitrates in corn, oat, wheat, soybean, and potato plots, all of which were seeded to wheat in the fall of 1923.

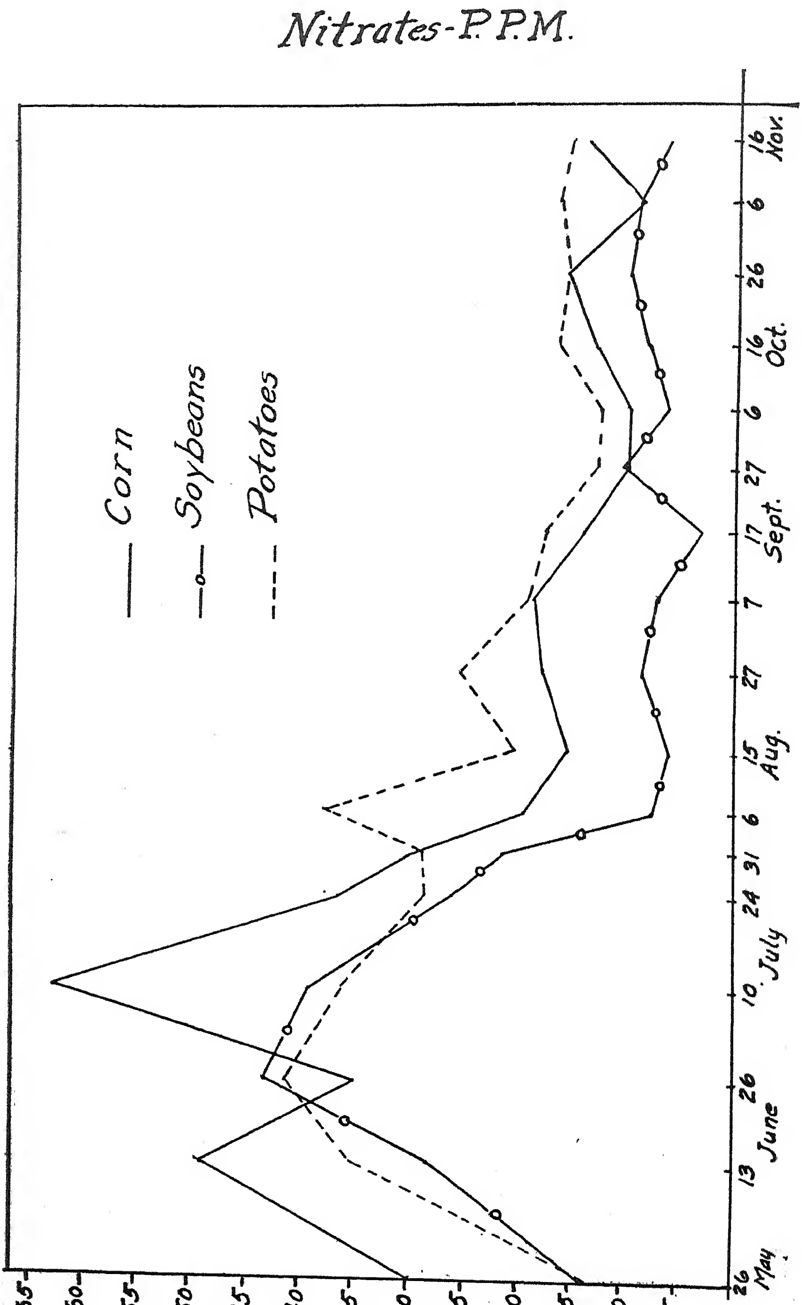

FIG. 6. Graphs of nitrates in corn, soybean, and potato plots during the season of 1923.

quantity of nitrates found in these plots on that and subsequent dates is shown in Figure 2. By way of comparing further the effect of potatoes with that of other crops, there is included in this figure also, the nitrates found in three fields, one each of corn, oats, and soybeans. These three fields are among the most fertile to be found anywhere on the station farm. In all of the plots, the nitrates rank above those found in the corn, oat and soybean fields. The probable reason for the relatively low nitrate content of two of the potato plots is the fact that in one case the potatoes had been preceded by corn; in the other by soybeans, both heavy consumers of nitrogen. The other four potato crops followed clover.

The determination of nitrates in plots of wheat following the same six crops was repeated in the fall of 1922 and the results, shown in Figure 3, conform closely to those obtained in 1921.

That the variation is not accidental, but develops as a result of the kind of crop grown is indicated by the work on another set of plots where the sampling was started in the spring at planting time, and continued throughout the growing season, while the corn, potatoes and soybeans occupied the ground. At the end of the season the quantity of nitrates, shown in Fig. 4, varied widely; the rank in descending order being potatoes, corn, and soybeans.

The finding of relatively high nitrates after potatoes is in accord with the work of King and Whitson (2)[3], Stewart and Greaves (6), and Lyon and Bizzell (4).

Nitrate determinations were continued on the two sets of plots in 1923 but with different results. In both sets of plots the nitrates found in the potato plots were conspicuously lower than in the two preceding years, as shown in Figures 5 and 6. Such a result, however, is to be expected, now and then, providing it is assumed that high wheat yields following potatoes are dependent on high nitrate content of the soil, because, as has already been pointed out, wheat yields following potatoes are not always relatively high. The nitrates therefore, ought not to be and apparently are not always present in great abundance in potato soil.

However, if nitrate nitrogen in potato soil is high in some seasons, then why is it not high in others? That is a fair question. Perhaps rainfall is an important factor, nitrates decreasing as rainfall increases. If high nitrates are correlated with low rainfall then from the quantity of nitrates found in the potato plots in the early fall of 1921, of 1922, and of 1923, shown in Figures 1, 3, and 5, one would

[3]Reference by number is to "Literature Cited," p. 534.

expect the preceding weeks, particularly the month of August, to have been rather dry in 1921 and 1922, and wet in 1923. According to weather records at Wooster, this is true. The rainfall for August in 1921, 1922, and 1923 was 1.85, 1.17, and 4.70 inches respectively. Considering the nitrates found during the fall period as a whole, then, on the assumption that high nitrates are correlated with low rainfall, one would expect the rainfall to have been lowest in 1922 because that is the only one of the three falls in which the nitrates were not only high in September but remained so to the end of November. The total rainfall for the months of August, September, October, and November in each of the years 1921, 1922, and 1923 was 15.48, 5.43, and 11.98 inches respectively. The yield of the wheat crop on the potato plots following the low nitrates in 1921 and the high nitrates in 1922 was 33.50 and 42. 87 bushels respectively.

The suggested relation between nitrates and rainfall raises an interesting question; because, if it should be shown eventually that high wheat yields are dependent on high nitrates and that high nitrates in turn are dependent on low rainfall, then it follows that high wheat yields should be correlated with low rainfall, a proposition which is not now accepted by all students of these problems.

From the foregoing remarks relating to the influence of nitrates on wheat yields it appears that the latter are closely related to the former and that the nitrate content of a wheat seed-bed may be materially affected by the preceding crop, potatoes being especially favorable and soybeans and corn particularly unfavorable for the accumulation of soil nitrates.

SOURCE OF NITRATES

Whence then come the nitrates in the case of the potatoes? Cultivation may be a factor. That cultivation increases nitrates on the Wooster silt loam was brought out in a late-cultivation-of-corn test made in 1921. After the ordinary time of discontinuing cultivation, a portion of a certain field of corn was given three later cultivations. These were made July 22, August 1, and August 12. An area parallel and adjoining the first was left without these three later workings. Across the middle of both plots, nine rows of corn were removed on the date of the first cultivation, thus leaving that part of each plot fallow. On this bare space, two series of nitrate determinations were run throughout the remainder of the season—one on the cultivated and one on the uncultivated portion. The results, therefore, represent the difference in development of nitrates due to cultivation on land which had already produced a growth of corn to the earing stage.

Samples were taken thirteen times, the last being gathered November 26. The nitrate nitrogen found averaged 37 parts per million on the cultivated portion and 31 on the uncultivated.

This experiment was repeated in 1922 and again in 1923. In both of these years there was a gain for cultivation, but it was no more marked in either of them than it was in 1921. The increasing of nitrates from cultivation is not in accord with the work of Call and Sewell (1) but it does agree with that of Lyon (3).

Cultivation alone, certainly, is not adequate to account for the quantity of nitrates sometimes found in potato ground. Moreover, there is much less accumulation in corn and almost none in soybean ground, and both of these are intertilled crops, the same as potatoes.

The writers are not unmindful of the supposition that in the development of tubers symbiosis is essential. If this be true, it means that two organisms are working together, and some time it may be demonstrated that because of this combination the potato is able to gather nitrogen from the air.

However, in seeking to explain the source of nitrates, it is perhaps well not to overlook two things; namely, (1) the nitrogen requirement of the crops concerned and (2) the age of potatoes at which they assimilate most of their nitrogen.

THE NITROGEN REQUIREMENT OF CERTAIN CROPS

With the exception of potatoes, the figures in the following table are adapted from "Soil Fertility and Permanent Agriculture" by Hopkins. The requirement of potatoes is a little less than that of clover and soybeans, practically the same as corn, and more than that

Kind of crop	Yield per acre	Nitrogen removed per acre, entire crop
		lbs.
Corn	75 bushels	111.00
Oats	75 "	72.75
Wheat	37.5 "	72.00
Clover	3 tons	120.00
Soybeans	20 bushels	127.20
Potatoes	200 "	110.00

of either oats or wheat. However, 70 of the 110 pounds removed by the potatoes is contained in the stems and leaves and is, therefore, not removed from the soil at all. If the entire 70 pounds was available to the succeeding wheat crop, that alone would satisfy the nitrogen requirement of a 36-bushel per acre wheat yield. Probably not all of

this nitrogen becomes available to the following wheat crop; but the rapidity with which the leaves decay and are thus returned to, and incorporated with, the soil suggests that a considerable part of it is, because approximately two-thirds of the nitrogen carried in the tops is contained in the leaves.

But even if all the nitrogen of the tops was liberated immediately, that would not account for the accumulation of nitrates found in the early fall because that nitrate nitrogen was present in the soil before the potatoes were dug. This leads to a discussion of the second point.

THE AGE AT WHICH POTATOES TAKE UP NITROGEN

According to Wilfarth *et al* (7), the nitrogen requirement of the potato is about satisfied by the middle of August. If this be true, then so far as the one element nitrogen is concerned, land devoted to the production of potatoes is practically fallow for a month or six weeks before wheat seeding time. And fallowing favors the accumulation of nitrates. An instance of this is afforded by results obtained in the late-cultivation-of-corn test to which reference has already been made. In this test nitrate determinations were made also on soil samples taken from the cropped as well as from the uncropped or fallow land. On the cropped land the nitrates averaged 17 parts per million; on the fallow, 34 parts per million. The experiment was repeated in 1922 and again in 1923 and in both years the results were similar to those found in 1921.

Land growing a crop of millet in the summer of 1923 was sampled at regular intervals from July 10 to November 16, inclusive; 13 times altogether. It gave an average of 8 parts per million of nitrates. Fallow land adjoining and sampled in the same way gave an average of 29 parts per million. King and Whitson (2), also Stewart and Greaves (6), have reported similar results from fallowing.

In view of these results, it would seem rational to account for the abundance of nitrates sometimes found in wheat ground following potatoes on the assumption that such land, so far as the one element nitrogen is concerned, has been practically fallow for several weeks prior to seeding.

DISCUSSION

It may be claimed that if the high yields of wheat following potatoes are due to an accumulation of nitrates in the potato ground, then, since wheat yields well also following such crops as tomatoes and tobacco, one ought to find an accumulation of nitrates in soils on which these crops are grown.

In order to determine whether this be true, a series of nitrate

determinations was made on soil samples taken in the summer of 1923 from two adjoining plots on the station farm; one planted to tomatoes; the other to sweet corn. On each plot soil samples were taken at regular intervals on 12 different dates beginning August 1 and ending November 16. The nitrates found in the corn and tomato plots during the entire period of sampling averaged 12 and 31 parts per million, respectively.

In order to study this situation in relation to tobacco, there were selected in the Creston tobacco district, three fields, each of which was planted in part to corn, and in part to tobacco. Soil samples were taken on four different dates beginning August 9 and continuing to October 6. On each date two samples were taken from each field, one in the corn and one in the tobacco; both from adjoining areas. The nitrates found in the soil of the three fields were in every instance greater in the tobacco than in the corn section, the average of all determinations being 10 parts per million in the corn and 20 in the tobacco. In early August, the nitrates in the tobacco soil were much higher than in the corn soil, but later the difference was much less marked. The marked falling off in the tobacco soil was probably due to the heavy rainfall in August. Prior to August there had been but one month, May, since the beginning of the year in which the precipitation was up to normal. The total rainfall for June and July was only 4.07 inches or 4.13 inches less than the normal for those two months. (Normal rainfall equals the 35-year average at Wooster).

As between a symbiotic relation and fallowing, the writers prefer to ascribe the accumulation of nitrates to the latter because such an assumption accounts for the accumulation of nitrate nitrogen in tomato and tobacco soils as well as in potato soils. If the accumulation of nitrates in potato ground is explained as the result of symbiosis, then no explanation is forthcoming to account for such accumulation in tomato and tobacco soils, because, so far as the writers are aware, no relation of this kind has ever been claimed for either of these two crops.

SUMMARY

Experimental evidence confirms the impression that wheat following potatoes does, on the average, yield a little higher than does wheat following most other crops, but there are many years in which this does not hold true.

At the end of many seasons, the nitrate content of potato ground is much higher than is that of corn, oat, wheat, clover, or soybean ground. This may account for the relatively high yields of wheat

that are frequently obtained when this crop follows potatoes.

High nitrate content of potato ground may be due in part to the relatively small amount of nitrogen removed by the tubers and in part to a fallow condition of the ground which seems to obtain during the last weeks it is occupied by the potato crop.

LITERATURE CITED

1. CALL, L. E., and SEWALL, M. C. The soil mulch. *In* Jour. Amer. Soc. Agron. 9:49–61. 1917.
2. KING, F. H. and WHITSON, A. R. Development and distribution of nitrates and other soluble salts in cultivated soils. Wis. Ag. Exp. Sta. Bull. 85. 1901.
3. LYON, T. L. Intertillage of crops and formation of nitrates in soil. *In* Jour. Amer. Soc. Agron. 14:97–109. 1922.
4. LYON and BIZZELL. Some relations of certain higher plants to the formation of nitrate in soils. Cornell Agr. Exp. Sta. Memoir 1. 1913; 5-III, 1913.
5. Monthly Crop Report, U. S. Dept. Agr. July, 1918.
6. Stewart, Rob't and Greaves, J. E. A study of the production and movement of nitric nitrogen in an irrigated soil. Utah Agr. Exp. Sta. Bul. 106. 1919.
7. WILFARTH, H., ROMER, H. and WIMMER, G. On the assimilation of the elements of nutrition by plants during different periods of their growth. Ducal Ag. Exp. Sta. at Bernburg in Anhalt, Germany. ———

HYBRID VIGOR IN SOYBEANS[1]

J. B. WENTZ and R. T. STEWART[2]

Hybrid vigor has been noted by plant hybridizers from the very earliest to the late workers. East and Jones[3] have published a complete review of the literature on this subject, presenting a large number of instances of vigor in F_1 plants as well as a review of the theories on the cause of hybrid vigor, or heterosis. The writers of this paper, however, have not been able to find any such data for soybeans. This probably is due to the fact that the soybean is a comparatively new crop to the plant breeder, and also to the fact that very small numbers of hybrids have been produced on account of the difficulty of manipulating the flowers.

EXPERIMENTAL WORK

There is presented in this paper some data on the vigor of F_1 soybean hybrids as compared to their parents. These hybrids were made in the summer of 1922 by William T. H. Ho.[4] Nine different varieties were used in the crosses reported, in the following combinations.

[1]Contribution from the Department of Farm Crops, Iowa State College, Ames' Iowa. Received for publication June 10, 1924.

[2]Associate Professor and student, respectively.

[3]EAST, E. M., and JONES, D. F. Inbreeding and Outbreeding. J. B. Lippincott Co., Philadelphia. 1919.

[4]A graduate student in the Department.

Cross No.	Female	Male	Number of hybrids obtained
5	Wisconsin Black	Mandarin	1
64	Ogemaw	Soysota	2
73	Ogemaw	Soysota	2
50	Soysota	Ogemaw	3
65	Ogemaw	Manchu	2
113	Ito San	Manchu	2
148	Early Brown	Ito San	1
150	Early Brown	Ito San	1
183	Ito San	Black Eyebrow	2
407	Manchu	Wilson	1

A number of other crosses were secured during the season, but only those are used in this study in which the F_1 hybrids could be identified with certainty by characters of plants and seeds other than vigor.

METHODS OF STUDY

When the cross pollinations were made, the plant from which pollen was taken for each pollination was tagged and an attempt made to secure seed from this pollen parent as well as the female parent. Due to the fact that the grasshoppers destroyed some of the tags, seed was not always secured from the pollen parent, but seed was always taken from the female plant.

When the hybrid seeds were planted in the spring of 1923, they were spaced four inches apart in rows four feet apart. In each case, the hybrid seeds of a cross and the parental seeds were planted in the same row.

Measurements on height of main stem in centimeters were taken on individual plants once a week from the time the plants were well above ground until maturity. When the plants were mature the pods were picked from each plant separately, threshed by hand, and the seed weighed in grams.

RESULTS

In this study hybrid vigor is measured in terms of height of plant in centimeters and yield per plant in grams. The two phases of the work are presented separately.

Height of Plants

Table 1 shows the average height of parental and hybrid plants for each cross, together with the number of plants averaged in each case. In four of the crosses both parents are included, while in the remain-

ing six crosses only the female parents are present. Under the heading "Average of parents," the figures for these six crosses include female parents only. This may not be considered a fair test where the male parents are missing. It may be thought that the increased height in the hybrids was due to the use of tall male parents, but it will be observed from the Table that in most of these six crosses medium to low varieties were used as male parents. For example, in cross number 50 Ogemaw, a very short-growing variety, was used as the male parent and the percentage increase in height of the hybrid over the female parent was 30.87.

It will be noted that in seven cases out of the ten the hybrids were taller than the parents. In one of the three cases which show a decrease in the hybrids as compared to the parents, cross number 5, the one hybrid plant present was badly injured by the road grader during its growth and no doubt was greatly handicapped. In the two crosses, numbers 113 and 407, all the plants were not entirely mature when frost came. This was particularly true of number 407.

While these data are not extensive there seems to be some evidence of hybrid vigor.

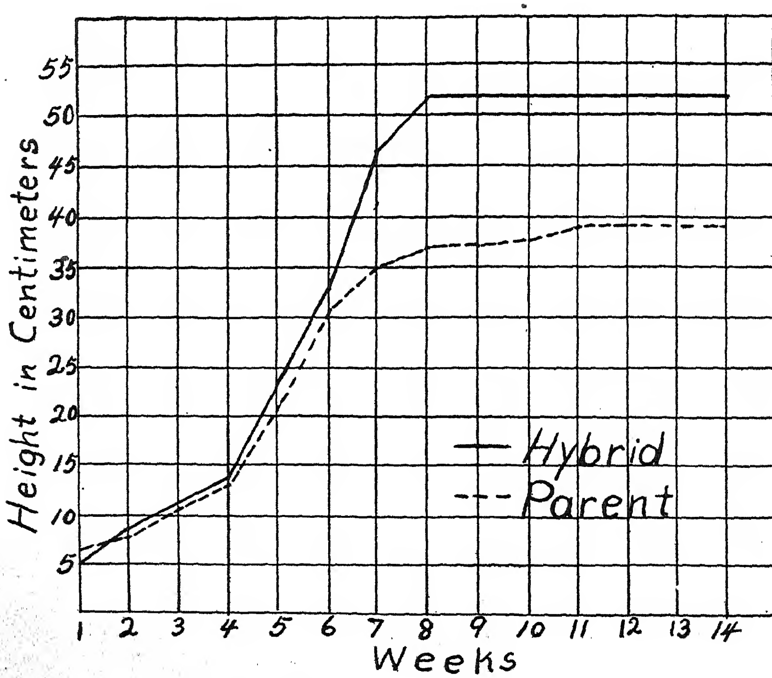

FIG. 1. Graph showing growth curve of hybrid as compared with female parent.

TABLE 1.—*Average height of F_1 plants at maturity as compared to parental plants.*

Female parent	Male parent	Cross No.	Final height in centimeters: Female, No. of plants	Female, Ave. height	Male, No. of plants	Male, Ave. height	Hybrid, No. of plants	Hybrid, Ave. height	Average of parents	Increase of hybrids over ave. of plants, Cm.	Increase of hybrids over ave. of plants, Percentage
Wis. Black	Mandarin	5	3	58.5			1[a]	54.5	58.5	— 4.0	— 6.84[b]
Ogemaw	Soysota	64	4	44.5			2	50.5	44.5	+ 6.0	13.48[b]
Ogemaw	Soysota	73	4	41.0			2	49.5	41.0	+ 8.5	20.73[b]
Soysota	Ogemaw	50	5	39.2			3	51.3	39.2	+12.1	30.87[b]
Ogemaw	Manchu	65	3	37.3			2	54.5	37.3	+17.2	46.11[b]
Ito San	Manchu	113	4	86.0	2	75.0	2	73.5	80.5	— 7.0	— 8.70
Early Brown	Ito San	148	3	76.6	3	86.0	1	85.0	81.3	+ 3.7	4.55
Early Brown	Ito San	150	1	78.0	4	84.6	1	91.0	81.3	+ 9.7	11.93
Ito San	Black Eyebrow	183	1	72.0			2	88.5	72.0	+16.5	22.92[b]
Manchu	Wilson	407	3	95.6	4	103.7	1	95.0	99.7	— 2.7	— 2.71

[a]This plant was injured by the road grader and probably is not representative.
[b]Female parents only.

TABLE 2.—*Average height of F_1 plants compared to average of parental plants, at bi-weekly intervals.*

(F = female parent, M = male parent, H = hybrid)

Cross No.	June 12			June 26			July 10			July 24			August 7			August 21			September 4		
	F	M	H	F	M	H	F	M	H	F	M	H	F	M	H	F	M	H	F	M	H
5				7.5			13.0		5.0	24.0		13.0	40.0		25.0	54.5		44.0	57.0		54.0
64	10.0		6.0	20.2		15.5	33.0		31.5	44.5		49.5	44.5		50.5	44.5		50.5	44.5		50.5
73	4.7		9.0	16.0		16.0	31.5		34.5	40.5		42.5	41.0		49.5	41.0		49.5	41.0		49.5
50	5.7		5.0	10.4		10.6	20.2		23.3	35.0		46.0	37.2		51.3	39.2		51.3	39.2		51.3
65	5.1		3.7	13.3		13.5	29.3		22.5	37.0		47.5	37.3		54.5	37.3		54.5	37.3		54.5
113	3.7	7.0	5.5	10.8	9.5	11.5	20.2	17.5	20.5	33.6	28.5	35.5	51.2	42.0	56.0	72.0	57.5	71.0	81.6	75.0	73.5
148	6.0	6.3	10.0	12.0	13.0	13.0	15.6	21.6	25.0	28.0	26.6	42.0	48.6	44.6	64.0	69.3	66.0	80.0	75.3	83.6	85.0
150	8.5	5.6	7.0	10.5	11.0	12.0	23.0	18.6	24.0	40.5	36.3	47.0	63.0	56.0	65.0	78.0	75.0	86.0	78.0	84.6	91.0
183	6.0		8.0	10.0		12.5	17.0		20.5	33.0		35.5	51.0		60.0	68.0		80.5	72.0		88.0
407	4.5	5.0	7.0	10.0	7.0	12.0	18.0	15.5	24.0	34.0	29.7	45.0	55.0	45.0	57.0	71.6	77.7	86.0	88.3	93.2	95.0

TABLE 3.—*Average yield per plant of F_1 hybrids as compared to parental plants.*

Female parent	Male parent	Cross No.	Yield Per Plant in Grams: Female		Male		Hybrid		Average of parents	Increase of hybrids over parents	
			No. of plants	Ave. yield	No. of plants	Ave. yield	No. of plants	Ave. yield		Grams	Percentage
Wis. Black	Mandarin	5	3	14.10			1[a]	16.95	14.10	2.85	20.21[b]
Ogemaw	Soysota	64	4	11.60			2	43.99	11.60	32.39	279.22[b]
Ogemaw	Soysota	73	4	10.99			2	45.32	10.99	34.33	312.37[b]
Soysota	Ogemaw	50	5	15.97			3	33.26	15.97	17.29	108.27[b]
Ogemaw	Manchu	65	3	12.80			2	26.31	12.80	13.51	105.55[b]
Ito San	Manchu	113	4	18.06	2	16.52	2	36.71	17.29	19.42	112.32
Early Brown	Ito San	148	3	17.65	3	31.74	1	39.40	24.69	14.71	59.58
Early Brown	Ito San	150	1	14.30	4	25.24	1	79.05	19.77	59.28	299.85
Ito San	Black Eyebrow	183	1	10.30			2	50.92	10.30	40.62	394.37[b]
Manchu	Wilson	407	3	21.17	4	13.02	1	53.89	17.09	36.80	215.33

[a]This plant was injured by road grader and probably is not representative.
[b]Female parents only.

A very interesting part of the data on height of plants is that included in Table 2 where the heights of hybrids and parents are compared at bi-weekly intervals. It will be noted that there is very little evidence of hybrid vigor in the first six of the fourteen weeks of the growing period. For example, examine the data in this table for the seven crosses which showed hybrid vigor as expressed in final height in Table 1 and it will be seen that the difference in favor of the hybrids at the end of six weeks is so very small that one could hardly say there is any evidence of hybrid vigor. However, if the data for the eighth and following weeks is taken it will be seen that the hybrids made rapid gains. The gain in height is practically all made during the two or three weeks just previous to the time that the plants stopped their growth. The time at which this rapid gain occurs depends upon the date of maturity of the varieties involved but the same general comparisons are seen in all the growth curves. Figure 1 shows the growth curve of hybrid number 50 as compared to the female parent. This same general curve is shown by all seven of the crosses showing hybrid vigor.

Yield Per Plant of Hybrids As Compared to Parents.

Table 3 presents the data on average yield per plant of the F_1 hybrids compared to the parents. Here there are some very striking figures on yield of F_1 hybrids as compared to parents. There is a decided increase in every case excepting in cross 5, where there is a small increase in spite of the fact that the single hybrid plant was badly handicapped by injury during the growing season. Eliminating this cross the percentage increase of hybrids over parent ranges from 59.58 to 394.37. There can be no doubt about there being a decided manifestation of heterosis in these crosses, even if it is assumed that high yielding males are used in all the cases where the yields of the male parents are missing.

SUMMARY

In this paper, data are presented concerning hybrid vigor in soybeans as expressed in height of plants and yield per plant, as well as data showing the growth curves of the hybrids as compared to parents.

The data on height of plants indicate some hybrid vigor in these crosses.

The growth curves of the F_1 hybrids show that the gain in height of hybrids, where there was distinct evidence of heterosis, was practically all made within the three weeks just previous to the time when the plants stopped growing.

The data on yield per plant show very striking evidence of hybrid vigor, giving percentage increases of hybrids over parents ranging from 59.58 to 394.37.

THE INFLUENCE OF BROKEN PERICARP ON THE GERMINATION AND YIELD OF CORN[1]

MARION T. MEYERS[2]

When external fungous organisms gain entrance through a broken pericarp and a saprophytic start in the endosperm of some grains during germination, it has been found that they may become parasitic on the seedling when they otherwise would not. The experiments reported in this paper were conducted to determine the relation of broken seed coats to readings for disease on the germinator and to seedling mortality and yield under field conditions.

REVIEW OF LITERATURE

Investigations of the root, stalk, and ear rots of corn by Hoffer and Holbert (9)[3], Duddleston (6), and Holbert and Hoffer (10) suggested the modification of the germination test for the detection of seed-borne infections which could not be otherwise detected, but which were a serious factor in controlling these diseases. Adams and Russel (1) noted that infections with common saprophytic molds, which were borne on the surface of the seeds and which caused very little, if any injury, under field conditions frequently interfered with the detection of serious pathogens on the germinator.

Fusarium moniliforme has been found to be carried almost universally in great abundance on seed corn, by the work of Valleau (17), Melchers and Johnston (13), and Branstetter (3). On the other hand, comparatively few ears infected with *Diplodia zeae* or *Gibberella saubinetii* were found. Whether the presence of *Fusarium moniliforme* is a serious detriment to seed corn is still in doubt, but it is evident that selection or treatment to eliminate this organism, which causes very conspicuous symptoms on the germinator, has little influence on yield under field conditions; as found by Valleau (18), Sherbakoff (16), and Melchers and Johnston (13 and 14).

Branstetter (3) further found, "that with a little care, one can select comparatively disease-free ears from a lot of corn, thus elimi-

[1]Contribution from the Department of Farm Crops, Ohio State University, Columbus, Ohio. Received for publication June 10, 1924.

[2]Assistant in Farm Crops.

[3]Reference by number is to "Literature Cited," p. 550.

nating the necessity of using the germinator as a means of detecting heavily infected seed ears." In view of the results reported above, selection of ears on the basis of disease readings on the germinator in many lots of carefully selected seed corn might be expected to give very little, if any, increase in yield. Kiesselbach (12) and the Iowa Agricultural Experiment Station (2), as well as Valleau (18), and Melchers and Johnston (13 and 14) cited above, obtained such negative results by the use of the germinator.

Melhus and Durrell (15) stated that saprophytic molds were often found growing from the break in the seed coat of kernels on the germinator, and that frequently these infections influenced the condition of the seedlings. Hurd (11) germinated wheat grains with broken and unbroken seed coats on blotters thickly sprinkled with spores of *Penicillium* sp. or *Rhizopus nigricans*. When the pericarp was broken over the endosperm, the molds obtained a saprophytic start which enabled them to become parasitic on the seedlings. Only a few such grains ever germinated, and the weak sprouts which resulted soon died. Sound grains and grains with the pericarps broken only over the embryo germinated normally on the same blotters.

Parallel cases in which it has been shown that molds are enabled to produce their characteristic effects only when given a saprophytic start, are reported by Harter and Weimer (8) working with *Rhizopus* infection of sweet potatoes, and by Durrell (7) working on the purple leaf sheath spot disease of corn. In the latter case, the various causal organisms were able to attack the living tissue only when growing saprophytically on agar placed inside the leaf sheath, or on pollen or pollen sacks washed there by rain or dew.

Brown (4 and 5) reported experiments comparing the yield from broken and entire seeds of corn under field conditions. The entire seeds usually outyielded the seeds without the protection of the pericarps several bushels per acre in several trials. The amount of reserve food available for the growth of the seedlings was assumed by the author to be the chief causal factor.

EXPERIMENTAL WORK

SELECTION OF MATERIAL

The experiments were begun in the fall of 1921. Because of the warm humid weather during the latter part of the growing season, there was an epidemic of *Diplodia zeae*, resulting in a large percent of rotted ears, in the crop of that year. It was believed that whenever a large amount of obviously rotted ears were found, there would be

present, also, many slightly infected ears which could not be detected in the selection of ears for seed.

From the crop growing on the Ohio State University farm, six lots of seed ears were selected from each of two varieties, Reid's Yellow Dent and Clarage. The first lots were selected from the stalks in the fall at the time the corn reached maturity, and the subsequent lots were selected at intervals from the field during the fall and winter and from the crib in the spring. Each lot consisted of two or more bushels, and as soon as selected was carefully stored on drying racks until tested.

In addition to this material, twelve bushels of seed corn were obtained, consisting of a lot of early Clarage selected from the stalks in northern Ohio, and a lot of Reid's Yellow Dent from central Ohio and of Johnson County White from southern Ohio, both selected at husking time.

In the various lots there were ears showing slight discolorations due to molds. These were most numerous in the Johnson County White. An effort was made to obtain material representative of what farmers had available for planting the following year, rather than the selection of unusual seed, thus indicating the nature of the seed corn situation in Ohio.

GERMINATION STUDIES

With this material, an attempt was made to determine the amount and the seriousness of the seed-borne infections with root rot organisms in the different lots. The modified rag doll was used and the methods described by Hoffer and Holbert (9), Duddleston (6), and Holbert and Hoffer (10) were followed. It was soon found that the disease readings in these tests were not consistent, although the greatest care was exercised in controlling the conditions.

Enough replicate dolls were made, using the same ears from each of the several lots, to compare the readings for disease on duplicate dolls from each lot, each day after germination, at 80° F. for six, seven, eight, and nine days. Where normal germination occurred, there were no signs of mold or lesions on the kernels or seedlings up to the sixth or seventh day, after which mold developed very rapidly, and nearly every seedling showed lesions. It was noted that there was as great variation in infection on the germinatior among the duplicate dolls from the same lot, run for an equal period of time, as among the dolls from the rest of the lots, germinated for the same length of time, provided the ears comprising them appeared equally sound. Many ears had kernels showing external evidences of mold, which in some

cases had advanced far enough to kill the embryo. In other cases, the molds did not affect the germination, but their presence resulted in an increased amount of disease on the kernels and seedlings on the germinator.

In the above tests, the first evidence of mold was a tuft of fungous hyphae growing from the break in the pericarp made by the knife when the kernel was removed from the ear. It appeared from these results that the modified rag doll germination test was simply a repetition, with corn, of experiments with wheat conducted by Hurd (11). This led to experiments to determine whether the usual external spore load of ordinary sound seed corn, by gaining a start in the endosperm through the break in the pericarp, was the source of most of the seedling injury on the germinator.

Dolls were made up from ears taken from several lots. The kernels were hand shelled to prevent breaking the pericarp. The pericarp of half the grains from each ear was broken over the endosperm with a knife. Some of the unbroken and of the broken grains were sterilized in a solution of mercuric chloride (2 parts to 1,000) and thoroughly washed in sterile water. The usual precautions were observed to avoid contamination in making up the dolls. From five to eight ears from one lot were used in making up a series of duplicate dolls. Each ear was represented by four adjacent rows of kernels as follows:

Row 1. Unbroken, sterilized
Row 2. Broken, sterilized
Row 3. Unbroken, unsterilized
Row 4. Broken, unsterilized

Several lots were so tested. The dolls were kept in the germinator at 80° F., and read on the sixth, seventh, eighth, and ninth days.

When the first readings were made, there was no evidence of mold in any doll, but in the subsequent readings mold had appeared and had increased according to the length of time in the germinator. Comparison of the rows in the doll from any ear gave the following results:

Row 1. (Unbroken, sterilized) Kernels and seedlings usually free from lesions and evidence of mold, even at the last reading.

Row 2. (Broken, sterilized) Lesions and signs of mold were few and increased in number and size slowly.

Row 3. (Unbroken, unsterilized) In most cases the amount of infection was about the same as in row 2.

Row 4. (Broken, unsterilized) Lesions and molds appeared

earlier, were more severe, spread more rapidly, and resulted in a decided reduction in the vigor of the seedlings when compared with any of the other rows.

Because of the accidental contamination which was sure to occur in making up a series of dolls in the preceding experiment, the method was modified after a few trials. Several duplicate dolls were again made up from groups of ten ears, using hand shelled kernels, one-half of which had been broken over the endosperm. The broken and unbroken kernels were placed in adjacent rows on the dolls. Half the dolls of each series of duplicates were treated with mercuric chloride (2 parts to 1,000) for 30 minutes to eliminate external infections, and then washed in running tap water for one hour. The remaining dolls were placed in tap water and allowed to remain there for one and a half hours. All were germinated at 80° F., and one doll of each half of the series was read on the eighth, eleventh, and fourteenth day. In this way approximately sixty ears from each lot of seed available were tested. In all, over fifteen thousand seedlings from treated dolls were compared with a like number from untreated dolls.

The seedlings in the treated dolls were not only free from mold in every case, even up to the fourteenth day, but were also more vigorous than those in the untreated dolls. The break in the pericarp made no difference in the treated dolls. On the other hand, as was also shown in the previous experiment, the seedlings in the non-sterile dolls from the grains with broken pericarps were more severely rotted than those from the grains with unbroken pericarps. The kernels with broken pericarps were very moldy, and the food contents largely destroyed, while the unbroken kernels were in very much better condition.

Inasmuch as the material tested was taken at random from all the lots of corn, occasionally ears were found which, before testing, were obviously moldy or dead. Where the rots had not progressed far enough to kill the embryo, surface sterilization was effective, and the seedlings produced were free from lesions. In the treated dolls, some of the grains developed a reddish or purplish discoloration of the pericarp, extending from the tip cap about one-third the length of the kernel. The cause of this discoloration was not evident before testing. Such grains germinated normally and the seedlings showed no lesions. In the various lots, 5 to 20 percent of the ears had a few such kernels. This would seem to agree with the results obtained by Valleau (17). The discoloration was assumed to be due to *Fusarium moniliforme*

present (as an internal parasite) in the grain after surface sterilization.

The results of the above experiments indicate that after careful visual selection (with the one exception noted) seed corn carries only external infection which may be eliminated by surface treatment, after which the broken pericarp is not a factor in seedling vigor. On the other hand, in dolls containing both broken and unbroken kernels prepared by the ordinary modified rag doll method, infection and subsequent mold growth are greater in the broken kernels, where the fungi present gain entrance and a saprophytic start in the endosperm. It appears that surface-borne infections are largely responsible for the readings taken as evidence of disease present in the ears in the ordinary modified germination test.

FIELD EXPERIMENTS

All plots in the field experiments were replicated three times, and the values reported are the average of the three plots, except in the case of the ear-to-plot test, conducted in 1922, in which the comparison is on the basis of the average of two sets of ten plots each. In 1922, all plots consisted of three rows, 31 hills long. The center row only was harvested, eliminating the end hills together with the border rows. In 1923, all plots consisted of four rows, which were 31 hills long in two replications and 33 hills long in the other. The two inside rows were harvested seaprately, eliminating the outside rows and the end hills. The sum of the two rows gave the yield of the plot. Each year, the hills were 42 inches apart each way and three kernels were planted per hill without thinning the resulting stands, except in the case of one set of plots in 1923, which was planted at the rate of four kernels per hill and thinned to three plants per hill. The seeds were planted May 20, in 1922, and May 6, in 1923. The season of 1922 was very favorable for the germination and growth of the corn and the soil was highly productive. Conditions immediately after planting in 1923 were very unfavorable for the germination of corn. Subsequently the season was favorable. The soil on which the experiments were conducted in 1923 was moderately unproductive. The plots were harvested October 7 to 10, in 1922, and on November 13, in 1923. The moisture content at harvest and the shelling percentages were determined, and the yield computed as bushels of shelled corn on the basis of a uniform moisture content of fifteen percent.

The first field experiment was conducted to determine whether sound-appearing seed corn, showing good germination, could be

divided into inferior and superior yielding groups of ears on the basis of the readings for disease on the germinator.

In the spring of 1922, sixty-eight sound-appearing ears were selected from a crib of the University Reid's Yellow Dent corn. Duplicate tests of these ears were made by the usual modified rag doll method. Three ears failed to give perfect germination and were discarded. The remaining sixty-five ears were used in subsequent field experiments. The ten ears appearing most diseased, and the ten least diseased ears according to the readings in the two germination tests, were selected. These were planted in a series of ear-plots, alternating the plots of the diseased and disease-free ears. The results obtained are given in Table I.

TABLE 1.—*Yields obtained from ear-plots of ten least diseased and ten most diseased-appearing ears, selected on the basis of disease readings in two duplicate germination tests.*

	Yield in bushels per acre of shelled corn reduced to 15% moisture	
	Total	Unmarketable
Average of ten least diseased ears	88.56 ± 1.53	3.62
Average of ten most diseased-appearing ears	83.43 ± 1.64	4.50
Difference in favor of least diseased ears	5.13 ± 2.24	

$$\frac{\text{Dif}}{\text{E}}=2.29.$$

The average yield of the ten least diseased ears exceeded the average yield of the ten most diseased-appearing ears by 5.13 bushels per acre, which is only 2.29 times the probable error of the comparison.

The possibility of this difference being due largely to chance is further indicated by the results obtained in another series of plots. This series consisted of three plots, planted with composite seed as shown in Table 2.

TABLE 2.—*Yield obtained from plots planted with composite seed from (1) the ten least diseased ears, (2) the ten most diseased-appearing ears selected above, (3) from the entire lot of 65 ears without reference to the disease readings on the germination test.*

	Average yield of the three plots in bushels of shelled corn per acre reduced to 15% moisture	
	Total	Unmarketable
Composite seed of the least diseased ears	85.27 ± 2.36	2.46
Composite seed of ten most diseased appearing ears	83.30 ± 4.34	5.06
Composite seed of entire lot	91.68 ± 2.33	2.90

The results obtained in these experiments further support the conclusion *that careful visual selection is as effective in eliminating diseased ears as are disease readings on the germinator.* The germinator may be of some value, however, for determining viability.

Further field experiments were conducted during 1922 and 1923,

in order to determine the effect on yield of broken pericarp in the presence of molds under field conditions. Ten ears were selected from a lot of the University Reid's Yellow Dent, which had been gathered in the fall of 1921. These ears had been dried on racks in a heated building. The pericarps of one-half of the grains on each ear were broken over the endosperm by cutting off the dent of the kernel with a knife. The broken and unbroken kernels of the ten ears were used to make up two composite lots of seed. One-third of the grains in each lot received no special treatment; one-third was sterilized with mercuric chloride (2 parts to 1,000) for three minutes, then thoroughly washed; and one-third was inoculated with a spore suspension of *Penicillium* sp. The six classes of seed so prepared were planted in 1922, in a corresponding number of plots. The series was replicated three times. The stand was counted June 9, and the plots harvested October 7 to 10. In comparison with the plots planted with unbroken seed, the broken seed which was not inoculated gave a slight reduction in stand, but no reduction in yield. The inoculation of the unbroken seed had no effect on the stand or the yield obtained, but the inoculation of the broken seeds resulted in a remarkable reduction in both stand and yield, as shown in the data given in Table 3.

TABLE 3.—*Summary of stand and yield from plots planted in 1922 with broken and unbroken seed variously treated.*

	Average yield in bushels of shelled corn per acre reduced to 15% moisture		No. of plants missing from three replications				Difference in favor of plots from unbroken seed	
			June 9 in a possible total of 837		At harvest in a possible total of 261		June 9	
	Total	Unmarketable	No.	percent	No.	percent	No.	percent
Unbroken seed	83.34±1.59	4.33	52	6.2	19	7.3		
Broken seed	87.92±2.33	2.89	80	9.6	23	8.8	28	3.3
Unbroken sterilized seed	87.43±3.83	4.09	53	6.3	31	13.4		
Broken sterilized seed	87.69±1.64	3.75	97	11.6	30	13.0	44	5.3
Unbroken inoculated seed	88.16±1.17	3.13	68	8.1	28	12.1		
Broken inoculated seed	21.26±3.39	2.12	441	52.7	193	83.5	373	44.6

The broken seed coats without artificial inoculation apparently produced no bad effects on the plants under field conditions in 1922. Was this due to the unusually favorable conditions for germination and growth that season, and may the broken seed coat be a menace

under unfavorable field conditions? It seemed desirable, in view of this question, to repeat the experiments in 1923, using poor soil and early planting in order to obtain the least favorable conditions for germination and growth. Ten good seed ears were selected from a crib of the University Reid's Yellow Dent in the spring of 1923. The seed coats were broken on the crowns of half the kernels on each ear, as in 1922, and composites made of both the broken and unbroken seeds, omitting the artificial inoculation with *Penicillium*. A series of three plots was planted. The first plot was planted with unbroken seed at the rate of four kernels per hill, and the plants thinned to three stalks per hill. The second plot was planted with sound seed, three kernels per hill, and the stand was not thinned. The third plot was planted with broken seed, three kernels per hill, and the stand was not thinned. This series was replicated three times. Stands were counted and the thinning done June 7, when the plants were eight to twelve inches high. The plots were harvested November 13.

A significant reduction in both stand and vigor of seedlings was obtained in the plots planted with broken seeds. The difference in vigor became less evident as the season progressed and had disappeared by the middle of July. There was no significant difference in the yield of the three plots, as shown in Table 4.

TABLE 4.—*Summary of stand and yield from plots planted in 1923 with broken and unbroken seed.*

	Average yield of three plots. Bushels of shelled corn per acre reduced to 15% moisture		Number of plants missing in three replications totaling 1140 plants June 7th	
	Total	Unmarketable	No.	Percent
Pericarp unbroken. Planted 4 kernels per hill thinned to 3 plants	62.09±3.26	2.28		
Pericarp unbroken. Planted 3 kernels per hill. Not thinned	65.56±2.35	1.92	105	9.2
Pericarp broken. Planted 3 kernels per hill. Not thinned	63.53±1.73	1.08	333	29.2

From the results of the field experiments with broken and unbroken pericarps, it may be concluded that in the presence of an unusual spore load under favorable conditions for germination, or with the usual spore load under unfavorable conditions for germination, the breaking of the seed coat results in a decided reduction in the stand obtained from good seed corn. An unbroken seed coat is effective and valuable protection against molds under most field conditions. The broken pericarp is the point of entrance of fungi,

whose subsequent growth sometimes kills the seedling or reduces its vigor. Favorable conditions for growth may offset the latter condition, and it may thus be assumed that the stand was not reduced either year to the point where it became a limiting factor in determining yield. In 1922, the favorable conditions for germination gave nearly full stands, even with broken uninoculated seeds, and the maximum yield of the good soil was obtained. In the following year, the unfavorable condition for germination gave a marked reduction in stand and vigor. However, the thin stand happened to be about right for maximum production under the conditions prevailing. The fact that this resulted in no reduction in yield in comparison with unbroken seed should not obscure the main point, which is, that seedling mortality was increased from 9.2 percent with unbroken pericarps to 29.2 percent when the pericarps were broken.

SUMMARY

Laboratory experiments with several bushels of seed corn from six strains obtained from northern, southern, and central Ohio, indicated that the disease readings on the germinator were no more discriminating than careful examination of the ears before testing. As ordinarily handled, all seed corn is exposed to surface contamination with spores of many species of fungi. Under the unusual conditions of moisture and temperature prevailing on the germinator, the molds borne in this manner cause serious injury to the seedlings of even carefully selected seed corn. When the seed coat is broken, as it usually is in most seeds placed on the germinator, the molds obtain a saprophytic start in the endosperm and the injury to the seedlings is greatly increased.

Field experiments gave no significant increase for disease-free ears selected on the basis of disease readings on the germinator from carefully selected seed corn, over the most diseased-appearing ears, or over ears taken from the lot without reference to diseased appearance on the germinator, thus substantiating the indication obtained in the laboratory experiments.

Under field conditions, reduced stands were obtained from seeds with broken seed coats. With favorable conditions for germination, such as prevailed in 1922, the stands from the broken seeds which were not inoculated were only slightly reduced. With unfavorable conditions for germination as prevailed in 1923, the stand from the broken seeds was reduced approximately 30 percent, and the vigor of the seedlings very decidedly lessened in comparison with the seedlings from unbroken seeds, which showed a reduction of about 10 percent in

stand. Inoculation of broken seeds with spores of *Penicilium sp.* reduced the stand to 396 plants from a possible 837. Only 55 percent of these survived till harvest. An unbroken seed coat proved to be complete protection against infection with the same spores.

Under the conditions of the experiments in the two years, the reduced stands did not affect the yield in either case except in the plots planted with broken inoculated seed in 1922.

The writer wishes to express his appreciation to Dr. J. B. Park under whose direction the work was done, for valuable suggestions, and encouragement throughout the progress of the experiments.

LITERATURE CITED

1. ADAMS, J. F., and RUSSEL, A. M. *Rhizopus* infection of corn on the germinator. *In* Phytopath. 10:535–543. 1920.
2. Annual Report of the Iowa Agr. Exp. Sta. 1920. Corn root rot. p. 33.
3. BRANSTETTER, B. B. Fungi internal to Missouri seed corn of 1921. *In* Jour. Amer. Soc. Agron. 14:354–357. 1922.
4. BROWN, E. B. Relative yields of broken and entire kernels of seed corn. *In* Jour. Amer. Soc. Agron. 12:196–197. 1920.
5. ———— Effects of mutilating the seeds on the growth and productiveness of corn. U. S. Dept. Agr. Bul. 1011. 1922.
6. DUDDLESTON, B. H. The modified rag doll and germinator box. Ind. Agr. Exp. Sta. Bul. 236. 1920.
7. DURRELL, L. W. A preliminary study of the purple leaf sheath spot of corn. *In* Phytopath. 10:487–495. Nov. 1920.
8. HARTER, L. L., and WEIMER, J. L. The relation of the enzyme pectinase to infection of sweet potatoes by *Rhizopus*. *In* Amer. Jour. Bot. 10:245–258. 1923.
9. HOFFER, G. N., and HOLBERT, J. R. Selection of disease-free seed corn. Ind. Agr. Exp. Sta. Bul. 224. 1918.
10. HOLBERT, J. R., and HOFFER, G. N. Control of the root stalk and ear rot diseases of corn. U. S. Dept. Agr. Farm. Bul. 1176. 1920.
11. HURD, ANNIE MAY. Seed-coat injury and viability of wheat and barley as factors in susceptibility to molds and fungicides. *In* Jour. Agr. Res. Vol. 21:99–122. 1921.
12. KIESSELBACH, T. A. Corn investigations. Neb. Agr. Exp. Sta. Res. Bul. 20. 1922.
13. MELCHERS, L. E., and JOHNSTON, C. O. Corn root stalk and ear rot disease investigations in Kansas: Report of progress in 1922. *In* Phytopath. 13:52. 1923.
14. ———— Second progress report for 1923. On studies of corn seed germination and the prevalence of *Fusarium moniliforme* and *Diplodia zeae*. *In* Phytopath. 14:45. 1924.
15. MELHUS, I. E., and DURRELL, L. W. Dry rot of corn. Ia. Agr. Exp. Sta. Cir. 78. 1922.
16. SHERBAKOFF, C. D. Common molds of corn seed in relation to yield. *In* Phytopath. 14:46. 1924.
17. VALLEAU, W. D. Seed corn infection with *Fusarium moniliforme* and its relation to the root and stalk rots. Ky. Agr. Exp. Sta. Bul. 226. 1920.
18. ————Studies on seed infection, ear types and yield, and the isolation of strains of corn showing specific reactions in the germinator. *In* Phytopath. 14:46–47. 1924.

THE EFFECTS OF FERTILIZERS ON THE YIELD AND THE EAR CHARACTERS OF CORN[1]

T. K. WOLFE[2]

In recent years, a considerable amount of work has been done in studying the relation between ear characters of corn and yield. The bulk of the data indicates that there is little, if any, relation between most of the ear characters and yield. Since fertilizers often have a marked effect on yield of corn, it may be worth while to determine the effect of fertilizers on the ear characters as well as on the yield. In this paper, data are presented which show the effects of certain fertilizers on yield and on ear characters of corn.

EXPERIMENTAL WORK

The data presented in this paper were secured during the years 1922 and 1923, from a 4-year rotation experiment of corn, wheat, grass and clover two years, which has been conducted since 1909. The soil was Hagerstown silt loam and the fertilizers, as shown in Table 1, were applied annually.

The Silver King variety of corn was used and 200 ears were selected at random from each treatment. The method used in securing some of the ear characters may need explanation. The characters, with exception of yield of shelled corn per acre, were determined for each ear and the results as given in Table 1 are averages for the 200 ears. The yield of shelled corn per acre was secured by weighing the grain from the entire plat for each of the treatments. Each of the plats were $\frac{1}{16}$ of an acre in size. The percentage of grain was calculated by dividing the weight of shelled corn by the weight of grain and cob. The average circumferences of the ear and the cob were obtained by averaging the butt and the tip circumferences. The taper factor, which denotes the cylindricity of the ear or the tendency of the ear to taper, was obtained by dividing the tip circumference of the ear by the butt circumference. The nearer the factor approaches unity the more cylindrical is the ear.

The average length of kernel was found by subtracting the average circumference of the cob (b) from the average circumference of the ear (a) and then using the formula $a\text{-}b = 2\pi r$. In the equation, r is the length of the kernel.

[1]Contribution from the Virginia Agricultural Experiment Station, Blacksburg, Va. Received for publication June 12, 1924.

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RESULTS OBTAINED

In Table 1, data are presented showing the effects of fertilizers on yield and on ear characters of corn.

Table 1. The effects of fertilizers on the yield and the ear characters of corn. 2-year average, 1922-1923.

Characters	Treatment[a]				
	Check	N-K	P	N-P-K	M
Weight of grain, gms.	157.71	186.26	196.53	210.47	209.78
Weight of cob, gms.	29.91	32.68	33.69	35.76	39.56
Percentage of grain	83.84	84.82	85.14	85.29	83.99
Circumference of ear, in.	6.04	6.07	6.24	6.38	6.36
Circumference of cob, in.	3.65	3.76	3.77	3.83	3.89
Taper factor	.93	.94	.95	.95	.93
Length of ear, in.	6.72	6.98	7.27	7.35	7.44
Length of kernel, in.	.359	.376	.391	.406	.397
Number of rows	15.05	14.97	15.22	15.78	15.91
Yield of shelled corn per acre, bus.	28.50	49.06	56.23	63.50	63.81

[a]In the treatments N means 308 pounds per acre of dried blood containing 16 percent ammonia; P, 438 pounds of acid phosphate containing 16 percent P_2O_5; K, 100 pounds of muriate of potash, containing 50 percent K_2O; and M, 4 tons of stable manure.

It may seem from Table 1 that the fertilizers used have increased the yield of corn very materially as compared with the check plat. Also, the fertilizers have, with one exception, made the ear characters more pronounced as compared with the check. The one exception is found in case of number of rows where the number is less for the nitrogen-potassium plat than for the check, but the difference is not great. In most instances the complete fertilizer gave nearly as good or better results than the stable manure. The stable manure supplied approximately 48 pounds each of nitrogen and potash and 24 pounds of phosphoric acid annually. The complete fertilizer supplied 40 pounds of nitrogen, 70 pounds of phosphoric acid, and 50 pounds of potash. The complete fertilizer was more favorable in its effect on ear characters and yield than was acid phosphate. In case of acid phosphate the effects were superior to those produced by nitrogen and potassium in combination. With the exception of number of rows, and the difference is very small, nitrogen and potassium in combination were more favorable in their effects than the check.

It seems that the fertilizers which affect yield favorably also have a favorable effect on the ear characters.

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RESEARCH FUNDAMENTAL TO THE SOLVING OF CROP-PLANT PROBLEMS[1]

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The purpose of the present symposium is to focus attention on some much needed lines of fundamental research in the field of botany and allied sciences. Progress in the production of crop plants now is greatly hampered by lack of more exact and intimate knowledge of the relationships, structure and functioning of the plants themselves. The topics suggested for this symposium reflect the lines along which this knowledge of the more important crop plants is needed, namely, taxonomy and mycology, morphology, physiology, cytology, genetics biochemistry, and edaphics, or soil science.

The writer previously has pointed out (1),[3] that the beginnings of recent and modern botany are found in the writings of the herbalists dating from about 1537. These men were concerned primarily with useful plants, chiefly cultivated. They amassed a great volume of information, interesting and fairly accurate, with regard to these plants.

Modern descriptive botany dates from about the beginning of the 18th century, or about 150 years after the herbalists had begun to produce their monumental works. The early descriptive or systematic botanists, the precursors of modern taxonomists, treated of all plants which came within their ken. There was no distinction made between wild and cultivated species in the matter of botanic atten-

[1]Introduction to the symposium held under the joint auspices of Section O, Agriculture, of the American Association for the Advancement of Science, and the American Society of Agronomy, at Cincinnati, Ohio, on December 28, 1923.

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[3]Reference by number is to "Literature Cited," p. 556.

tion given. Following them came the great and still existent array of so-called pure botanists, who confined their attention almost wholly to wild species with coincident neglect of cultivated plants.

The writer has speculated previously (1) as to the causes of this change. Perhaps it was due in part to developing means of transportation which enabled a much wider and more rapid outreach for material. This made an ever increasing number of wild species obtainable for study, both in their native haunts and in botanic gardens. Perhaps it was because most of the rapidly growing number of botanists could not afford to grow large numbers of species for study and so were compelled to study the self-propagated wild species. Perhaps it was due partly to the appeal to that weakness of human nature, the desire to see one's name in print. Publication of new species gave the most ample opportunity then as now. Perhaps it was just a growing fashion, gaining adherents as other fashions do. Who knows?

What is known is that little further study of wild species was made by botanists. At the same time there developed gardeners and orchardists and farmers and physicians who began to study the culture and utilization of domesticated plants. The two groups have been independent and their paths divergent.

The taxonomy of thousands of groups of wild plants has been the object of most painstaking study. More recently morphologists, histologists, geneticists, cytologists, physiologists, and ecologists have made most wonderful additions to the sum total of knowledge concerning wild plants.

On the other hand, there has developed a very numerous army of men and women who are working with useful plants. These include agronomists, horticulturists, pomologists, nuciculturists, olericulturists, sylviculturists, foresters and florists, not to mention pathologists. Their prime concern has been with production, with masses of individuals rather than with individuals as such. Their object has been the acquisition of such knowledge as would result in increased pounds of starch, or protein, or oil, or fiber, or sugar, or total plant substance. Little attention has been given to the structure or function of these crop-plants.

They have solved most of simple pioneer problems of the production of the plants with which they work. As they progress to the attack on more complex and fundamental problems they come face to face with the need for far greater knowledge of the plants themselves. To find out what a plant will do is one thing. To find out

why it does so is quite a different thing and this is where the shock troops now are massed.

From the ranks of agronomists, horticulturists, pathologists, and their associated utilitarists have developed some splendid workers in taxonomy, mycology, morphology, histology, cytology, genetics, physiology and other ultimate and fundamental divisions of botany. With them are becoming associated in research on plant problems an equally fine corps of still narrower specialists primarily trained in these lines and paid by funds appropriated for solving economic problems in plant production.

The professional botanists of America stand second to none in the world. The great endowed institutions for research in America have a personnel and laboratory equipment for botanical study which never has been excelled. Their contributions to pure botany, including taxonomy, mycology, morphology, histology, cytology genetics, physiology and ecology excite the admiration and the envy of the workers with crop plants.

Why should not these two groups pool their resources and join hands in the solution of pressing economic problems? In another place the writer (2) has pointed out eight of the advantages resulting from the cooperation of different agencies in research. The reasons given were: (1) saving the cost of organizing and financing separate attacks on a common problem; (2) making possible a comprehensive survey of the problem and attack upon it; (3) enabling more prompt use by others of results gained by one group; (4) preventing waste of material not needed at one point or by one worker; (5) avoiding danger of divided allegiance by a supporting constituency; (6) obtaining larger results from the investment and increasing total funds available; (7) increasing the cooperative spirit within each institution, and (8) enabling better utilization of talents of individual workers.

In Scotland, Smith (3), in a recently published presidential address, summarizes the situation and the opportunity in the following words:

"This brief survey may suffice to emphasize that the progress of applied botany depends on the utilization of the latest researches of botany as a whole. Conversely, that the stimulus to further investigation in botany may come from the problems incidental to agriculture, forestry, and horticulture. Taxonomy or systematic botany has raised men skilled in detecting the differences in varieties so essential in plant breeding. Plant physiology with its laboratory equipment has placed the understanding of plant nutrition and plant response on a firm basis. Ecology, in its endeavours to ascertain the relation of plant to soil and climate by a study of the native plants, has led to a better concept of

the utilization of land for economic purposes. Mycology is saving millions sterling of crops that might have been destroyed by fungus pests. The linkage of so-called 'practice and theory' should be self-evident, if there ever was any doubt about it. The past fifty years have seen ever-increasing specialization in the various branches of botany, almost a separation of the schools. Yet the same period has seen the evolution of agricultural botany and other collateral branches of the parent botany, where the purpose is to join together link by link the facts bearing on the problems peculiar to the economic need."

Crop plants, in many cases, will furnish as excellent material for the thesis problems of graduate students, and of their professors, as will wild species. At the same time, these workers will feel that they are assisting in the solution of problems that directly affect the prosperity of nations and the comfort and happiness of countless human lives. Increasing populations, without equally increasing land areas make necessary more abundant and more certain production from the acres now tilled. Progress in applied science waits on this more intimate knowledge of our useful plants. No more inviting or worthy work awaits any who adventure into pure science.

LITERATURE CITED

1. BALL, CARLETON R. The relation of crop-plant botany to human welfare. *In* Am. Jour. Bot. 8:323–338, 1921.
2. BALL, CARLETON R. Federal and state cooperation in cereal research. *In* Proc. Assoc. Land-Grant Colleges 1921: 158–162, 1922.
3. SMITH, W. G. Agricultural botany in the past fifty years. *In* Trans. Bot. Soc. Edinb. 38: 77–84, 1922.

1a. TAXONOMY[1]

CARLETON R. BALL[2]

Two principal lines of taxonomic activity are needed to further our knowledge of crop plants. First, a monographing of those genera from which our crop plants have come or to which they are closely related. Second, the systematic comparison, description and classification of the cultivated varieties and forms of our crop plants themselves. Notable progress has been made in both lines but it is only a start compared to what is needed.

The study of the wild relatives of cultivated plants will require much time, effort, and expense. Well organized and well manned

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exploring expeditions must search the hinterlands of the world for these related forms. They must be collected, assembled and grown. They must be studied and compared under different sets of environing conditions. They must be described and classified and their degree of relationship to the cultivated forms made known. All this is properly the work of the trained botanist, assisted by the worker in economic lines. It will need to continue so long as the race endures and the needs of men increase.

The proper taxonomic treatment of the myriads of varieties and strains of each of our numerous cultivated plants is a herculean task. It involves the assembling of enormous quantities of material from the four corners of the earth. It requires the growing and study of the assembled varieties under many different sets of environing conditions through a series of years. It demands the taking of complete descriptive records throughout the period of experiment. It necessitates considerable skill in interpreting these data and in constructing accurate, natural and usable keys to separate the resulting groups and varieties. Finally it obligates the use of a consistent code of varietal nomenclature and the resolving of the existing confusion of varietal names in accordance therewith.

The assembling, comparison, description and classification of cultivated varieties, on the other hand, is a task primarily for the agronomist and horticulturist. The systematic botanist can assist but scarcely can conduct such investigations, though the methods and language of the published result must be those he uses, with some modifications. Those differences in form, structure, dimension and color which serve to separate species of wild plants are sufficient to separate only the varieties and strains of cultivated crops.

The presence of such marked differences led the professional botanists of a century and more ago to apply a Latin nomenclature to varieties of plants cultivated. This is an abomination. It has imposed an altogether unnecessary burden on agronomists and horticulturists with no compensating benefits. In fact the practice has led many workers in economic lines into great misconception of the scope and function of taxonomy. It has deterred others from attempting such classifications of crop plants as they were well prepared to undertake.

The acquiring of a fuller knowledge of the varieties of plants used for economic purposes and of their wild relatives has received an enormous impetus recently from two distinct causes. First, the settling of new areas having new requirements of climate and soil demands new kinds of crop plants with different adaptations. Second,

the new science of genetics has shown how to combine the desirable characters of parents in the offspring resulting from crossing the parent plants. Pure science and applied science must unite to find or to produce the plants required.

The writer has in preparation a comprehensive dicussion of this subject. It will contain an analysis of the publications in this country and abroad which have treated either the taxonomy of wild relatives of cultivated plants or the botanic comparison and classification of the varieties and forms of these cultivated plants themselves. This will involve reference to some hundreds of publications and is too extensive for the purposes of the present symposium. It is sufficient here to discuss briefly the present status of such work as has been done in America in the past 50 years or thereabouts and to point out some of the major taxonomic problems before plant investigators.

Each of the major groups of crop plants will be discussed separately, as follows: cereals, forages, fibers, forests, fruits, vegetables, flowers, sugar crops, oil crops and drug crops. It is realized that this is an incomplete and arbitrary grouping, but it should be sufficiently clear for the purposes of a brief summary.

CEREAL CROPS

The description and classification of cereals, like most modern systematic botany, dates from the classic work of Linné (29)[3] in 1753. At that time he described several species of cultivated wheats and of both wild and cultivated oats and barley. A discussion of the progress and the present status of wheat classification may be taken as fairly representative of that in the other major cereals.

WHEAT

Linné (29) named 5 species of wheat in 1753, the spring and winter forms of common wheat being considered two distinct species. Lamarck (28) in 1786 corrected this error and erected the new specific name *sativun* for the common wheats. Seringe (50) in 1819, treating of common and club wheats, probably was the first to discuss agronomic varieties.

Many other authors expanded the numbers of groups and varieties recognized in the half century that followed. In 1866, Alefeld (2) separated the cultivated wheats into several subspecies and numerous varietal groups, to each of which a Latin name was applied. Koernicke (25) in 1873, and Koernicke and Werner (26) in their classic two-volume work in 1885, expanded Alefeld's plan extensively, both

[3]Reference by number is to "Literature Cited," page 563.

as to Latin nomenclature and discussion and description of agronomic varieties. They named and keyed 150 groups of varieties and described the varieties themselves in detail, with history and synonymy. Since then much similar work has been done in India, Australia and Russia.

American authors began to describe wheat varieties fully 80 years ago and to attempt to classify them 65 years ago. With the exception of Carleton (10), they uniformly omitted the Latin nomenclature featured by Old World writers. Todd, in 1868 (56) made the suggestion that the Government straighten out varietal confusion and establish an intelligible description of each variety. This was done 54 years later when Clark, Martin and Ball (11) in 1922 published their classification of American wheats, in which about 230 recognized commercial varieties of the United States and Canada were fully described and keyed. After separating the wheats into the recognized commercial and botanical groups, common wheats, durum wheats, etc. the varieties are separated by use of the following characters in order of descending importance, namely: awns, glume pubescence, glume color, kernel color, kernel size, kernel hardness, seasonal habit, spike shape, etc. The Latin nomenclature is not used though it is given in parentheses in the keys for the sake of workers abroad who may be accustomed to it.

One large and continuing problem is to determine the origin and identity of new wheats appearing in commercial culture and to fit them to their place in the classification. Another problem is to determine the influence of environment on color of stem and glumes, on pubescence, on density of spike and on hardness of kernel.

There has not been much study of the wild relatives of wheat because these are comparatively few and only distantly related. Some study has been made of species of *Aegilops* and more is needed. Aaronsohn (1) and Cook (14) have written about the so-called "wild wheat" of Palestine, really a primitive emmer. A thorough survey of the extensive regions of early and long-continued culture of cereals is needed. These cover the Balkan States, Asia Minor, South Russia, Syria, Mesopotamia, the Caucasus, Chinese Turkestan and Persia, and include all the new States founded in that region as a result of the World War. This survey should discover all primitive forms of cereals under cultivation and any wild relative still existent there.

OATS AND BARLEY

The history of the taxonomic treatment of oats and barley is almost identical with that of wheat. In many cases the same writers

worked with all three crops. The chief major difference is that there are many wild species of both *Avena* and *Hordeum*. In the case of *Avena* especially, these are very closely related to the cultivated species or subspecies, of which they usually are held to be the progenitors. The wild barleys are less closely related to the cultivated, though Pammel, Ball and Scribner (37, p. 335-37, fig. 237) have reported an obscure wild species, *Hordeum pammeli* Scribner and Ball, of the Upper Mississippi Valley, which is very suggestive of the cultivated *H. vulgare hexastichon*.

The chief contributions to classifications of oats and barley in this country are Etheridge (15) on oats and Harlan (16, 17) and Wiggans (59) on barley.

The chief problem in the taxonomy of oats is the intensive study of the characters of the wild and supposedly wild species to determine their respective origins and limits, and their relationships to each other and to the cultivated oats. A similar study of cultivated oats is needed to determine origins and relationships and the cause of such common abnormalities as the so-called "false wild" forms.

FORAGE CROPS

The two chief groups of forages are grasses (*Gramineae* or *Poaceae*) and legumes (*Leguminosae* or *Papilionaceae*). In addition, there are special forage uses made of such diverse groups of plants as cacti (*Cactaceae*), saltbushes (*Atriplex* of *Chenopodiaceae*), sunflowers (*Helianthus* of *Compositae*), and others, as well as various root crops.

LEGUMES

Leguminous plants are found throughout the world and a very large number of genera contribute to the hay and pasture resources of different continents. Much painstaking study has been given to both cultivated and wild species and their varieties. Within the limits of this paper it is possible only to mention a few outstanding American examples of both classes.

Piper (39, 44) and Piper and Morse (45) have discussed the botany of numerous *Leguminosae*. McKee (31), McKee and Ricker (32), Oakley and Garver (34), Oakley and Westover (35), and Scofield (49) have contributed to our knowledge of alfalfa and other members of the genus *Medicago*. Kennedy (23, 24) and McDermott (30) have studied *Trifolium*. Coe (12), Pieters and Kephart (38) and Wilkins (62) have studied sweet clovers, while Schulz (48) in Germany has monographed the genus *Melilotus*. Piper (40, 41) and Wight (60) have studied the cowpea and other members of the genus *Vigna*. Ball (4), Piper (42), and Piper and Morse (46) have classified and described

American soybean varieties. Bort (8), Piper (43), and Piper and Tracy (47) have studied the botany of the velvet beans (*Stizolobium* spp).

The principal problems in the legumes are exactly those in other groups, like the cereals, namely a much better knowledge of characters as indications of relationships. As most legumes have been domesticated with relatively little change of form, it follows that an extensive study of wild legumes is likely to be well repaid. Further study of the species and varieties domesticated in other parts of the earth also is a promising field. Continued description and classification of the rapidly increasing number of domestic varieties, especially in cowpeas and soybeans, is imperative.

GRASSES FOR HAY, PASTURE, AND TURF

A very large proportion of the total quantity of grass hay and pasturage of the world is obtained from uncultivated species. In the United States, members of the genera *Agropyron*, *Agrostis*, *Bouteloua*, *Festuca* and *Poa* are abundantly used in the wild state and some species are cultivated widely. Of other genera such as *Andropogon*, *Bulbilis*, *Cynodon*, *Dactylis*, *Lolium* and *Phleum*, only a few species occur. Of *Bromus*, *Elymus*, *Panicum* and *Paspalum* there are many species but few are utilized. The wild and the cultivated species, both native and introduced, have been studied extensively by botanists and are treated both in manuals and in monographs of special groups or genera.

The chief problem in grasses is to study their characters so intensively that the particular features which make one species valuable and closely related ones relatively valueless may be made known and adequate and accurate descriptions and keys for separating them be constructed so that agronomists as well as professional botanists may know them.

FIBER, SUGAR, OIL, AND DRUG CROPS

Space lacks here to discuss what has been done in the study and classification of cotton, flax and other fiber plants, in sugar cane and sugar beets, in flax, sesame, and mustards, in cacao, coffee, hops, mints, and tobacco and the wild species closely related to them. Treatment of these is reserved for the fuller paper to follow. The problems of varietal description and classification and of study of wild relatives are the same as in other groups of crop plants.

FOREST CROPS

Taxonomic treatments of the plants useful in furnishing lumber and other forest products are exceedingly abundant and need not be

cited here. The different condition in forestry is due to the fact that nearly all the species are utilized in the wild rather than in the cultivated state. All manuals of botany, therefore, and all monographs of families, genera, or other taxonomic groups, are actual treatments of the plants utilized and of the wild relatives of such few as may be cultivated. Relatively much more is known of the botany of the useful trees, therefore, than of any other division of economic plants, not even excepting grasses.

FRUIT CROPS

Horticulture is an older art than agronomy. In some ways also it made an earlier advance in the last 40 years of intensive experimentation on crop plants. We might expect, therefore, to find the comparison and classification of fruit crops further advanced than that of field crops.

Budd and Hansen (9) in 1903 and Beach, Booth and Taylor (6) in their comprehensive treatment of the apples of New York, in 1904, have described and classified apple varieties. More recently Shaw (51) has determined that leaf characters, especially serration, may be used in separating varieties.

Several writers have proposed classifications of peaches. Onderdonk (36) developed one of the earliest and Hedrick and his associates (20) the latest and most comprehensive.

More study has been given to plums and cherries than to other groups of fruits by American authors because so many of the former have been derived from native species. Bailey (3), Willard and Bailey (63), and more recently Hedrick and his associates (18) have classified and described the cultivated plums and Hedrick and his associates (19) the cultivated cherries. Mason (33) has studied and described the southwestern species of *Prunus* most closely related to the peaches and almonds, while Wight (61) has given more attention to those representing the plums and cherries.

In the study of the citrus fruits, Swingle (53, 54, 55) has been one of the most consistent advocates of intensive research on wild relatives and has published extensively along this line. The papers cited are but a sample of those published. Hume (21) and Coit (13) have discussed the origin and botanical relationships of the several species of *Citrus* represented in cultivation in America.

Other writers have given attention to the taxonomy of the avocado, banana, cocoanut, date, fig, grape, mango, olive, pear, persimmon and pineapple, while still others have presented similar treatments of such small fruits as blackberries, raspberries and currants and their wild relatives.

VEGETABLE CROPS

In this group, derived mostly from commercial sources of supply, the numbers of named varieties run riot. Many such species are cultivated for their leaves (cabbage and related plants, cress, lettuce, spinach, etc.), or their roots (beet, carrot, parsnip, sweet potato, turnip, etc.), or bulbs (onion), or tubers (potato, artichoke). This has led to extreme diversity of form, size, color, and structure of these organs. Still others are grown for their seeds (beans, peas), or their fruits (cucurbits, egg plants, tomato), and the diversity is apparent in these structures.

Some good work has been done in this difficult field. Sufficient here to mention the classifications of the potato by Kohler (27) and Stuart (52); of beans by Jarvis (22) of Cornell and Tracy (57), and of lettuce by Tracy, Jr. (58).

The problems here have to do with numerous varieties of the domesticated plant rather than with wild relatives, though these never can be neglected with safety.

FLOWERS

Again space lacks for more than mere mention of the work of the New York Cornell Station, where Butchelor (5) has classified the peony, and Beal (7) the sweet pea. Several others have published on these flowers.

LITERATURE CITED

1. AARONSOHN, A. Agricultural and botanical explorations in Palestine. U. S Dept. Agr., Bur. Plant Indus. Bul. 180: 1–64, figs. 12, pls. 8. 1910.
2. ALEFELD, FRIEDRICH. Landwirtschaftliche Flora oder die nutzbaren kultivirten Garten- und Feldgewachse Mitteleuropa's. . . viii, 363 p. Berlin. 1866.
3. BAILEY, L. H. The cultivated native plums and cherries. New York Cornell Sta. Bul. 38: 1–73, figs. 14. 1892.
4. BALL, C. R. Soybean varieties. U. S. Dept. Agr., Bur. Plant Indus. Bul. 98: 1–28, figs. 2, pls. 5. 1907.
5. BATCHELOR, L. D. Classification of the peony. New York Cornell Sta. Bul. 306: 55–159, pls. 4. 1911.
6. BEACH, S. A., BOOTH, N. O., and TAYLOR, O. M. The Apples of New York, I. New York State Sta. Rpt. 1903, pt. 2, pp. XX+409, figs. 10, pls. 129.
7. BEAL, A. C. Sweet pea studies.—IV, Classification of garden varieties of the sweet pea. New York Cornell Sta. Bul. 342: 217–360, fig. 1, pls. 23. 1914.
8. BORT, KATHERINE S. The Florida velvet bean and its history. U. S. Dept. Agr., Bur. Plant Indus. Bul. 141: 25–32 (pt. 3), fig. 1, pls. 3. 1909.
9. BUDD, J. L., and HANSEN, N. E. American Horticultural Manual. II, Systematic pomology. New York: John Wiley & Sons, pp. 491, figs. 386, pls. 9. 1903.

10. CARLETON, MARK A. The small grains. xxxii, 699 p., figs. 183. Bibliography, p. 639–685. 1916.
11. CLARK, J. ALLEN, MARTIN, JOHN H., and BALL, CARLETON R. Classification of American wheat varieties. U. S. Dept. Agr. Bul. 1074: 1–238, figs. 76, pls. 60. 1922.
12. COE, H. S. An annual variety of Melilotus alba. *In* Jour. Amer. Soc. Agron. 9: 380–382. 1917.
13. COIT, J. E. Citrus fruits. The Macmillan Co., New York, pp. i-xx, 520 p., figs. 151, pl. 1. 1915.
14. COOK, O. F. Wild wheat in Palestine. U. S. Dept. Agr., Bur. Plant Indus. Bul. 274: 1–56, figs. 11, pls. 15. 1913.
15. ETHERIDGE, W. C. A classification of the varieties of cultivated oats. New York Cornell Sta. Mem. 10: 81–172, figs. 22, pls. 22. 1916.
16. HARLAN, H. V. Some distinctions in our cultivated barleys with reference to their use in plant breeding. U. S. Dept. Agr. Bul. 137: 1–38, figs. 16. 1914.
17. ————. The identification of varieties of barley. U. S. Dept. Agr. Bul. 622: 1–32, pls. 4. 1918.
18. HEDRICK, U. P., et al. The plums of New York. New York State Sta. Rpt. 1910, pt. 2, pp. XII+616, pls. 100.
19. ————. The cherries of New York. New York State Agr. Exp. Sta. Rpt. 1914, pt. 2, pp. XII+371, pls. 57.
20. ————. The peaches of New York. New York State Sta. Rpt. 1916, pt. 2, pp. XIII+541, pls. 95.
21. HUME, H. HAROLD. Citrus fruits and their culture. 597 p., figs. 124, pls. 36. 1904.
22. JARVIS, C. D. American varieties of beans. New York Cornell Sta. Bul. 260: 153–255, pls. 17. 1908.
23. KENNEDY, P. B. Studies in Trifolium. I. Muhlenbergia 5: 1–13. pl. 1. 1909.
24. ————. Studies in Trifolium. II. Muhlenbergia 9: 1–29, pls. 5. 1913.
25. KOERNICKE, FRIEDRICH. Systematische Uebersicht der Cerealien und monocarpischen Leguminosen in Aehren, Rispen, Früchten, und Samen. 55 p., fold. tab. Bonn. 1873.
26. ——and WERNER, HUGO. Handbuch des Getreidebaues. 2 vol. Berlin. 1885.
27. KOHLER, A. R. Potato experiments and studies. Minnesota Sta. Bul. 114: 287–333, figs. 2. 1909.
28. LAMARCK, J. B. M. DE. Encyclopédie methódique. Botanique. t. 2. 1786.
29. LINNÉ (LINNAEUS), CARL VON. Species plantarum. t. 1. 1753.
30. MCDERMOTT, LAURA F. North American Trifoliums. San Francisco, 325 p., figs. 136. 1910.
31. MCKEE, R. Glandular pubescence in various Medicago species. *In* Jour. Amer. Soc. Agron. 10: 159–162. 1918.
32. ——and RICKER, P. L. Nonperennial medicagos: The agronomic value and botanical relationship of the species. U. S. Dept. Agr., Bur. Plant Indus. Bul. 267: 1–38, pls. 13. 1913.
33. MASON, S. C. The pubescent-fruited species of Prunus of the Southwestern States. U. S. Dept. Agr., Jour. Agr. Research 1: 147–178, figs. 8, pls. 8. 1913.

34. OAKLEY, R. A., and GARVER, S. Medicago falcata, a yellow-flowered alfalfa. U. S. Dept. Agr. Bul. 428: 1–70, figs. 23, pls. 4. 1917.

35. ——and WESTOVER, H. L. Commercial varieties of alfalfa. U. S. Dept. Agr. Farmers' Bul. 757: 1–24, figs. 7. 1916.

36. ONDERDONK, Gilbert. Peach culture in the extreme Southwest. U. S. Dept. Agr. Rept. 1887: 648–651. 1888.

37. PAMMEL, L. H., BALL, CARLETON R., and SCRIBNER, F. LAMSON. The grasses of Iowa, Part II. A description and geographical study of the grasses of Iowa. Ia. Geol. Surv. Supplementary Report 1903: 1–436, figs. 1–270, pl. A (map).

38. PIETERS, A. J., and KEPHART, L. W. Annual white sweet clover and strains of biennial form. U. S. Dept. Agr. Circ. 169: 1–21, figs. 8. 1921.

39. PIPER, C. V. The search for new leguminous forage crops. U. S. Dept. Agr. Yearbook 1908: 245–260, pls. 7. 1909.

40. ————. Agricultural varieties of the cowpea and immediately related species. U. S. Dept. Agr., Bur. Plant Indus. Bul. 229: 1–160, pls. 12. 1912.

41. ————. The wild prototype of the cowpea. U. S. Dept. Agr., Bur. Plant Indus. Circ. 124: 29–32, figs. 3. 1913.

42. ————. The name of the soy bean: A chapter in its botanical history. *In* Jour. Amer. Soc. Agron. 6: 75–84. 1914.

43. ————. The cowhage and related species. *In* Proc. Biol. Soc. Wash. 30: 51–62. 1917.

44. ————. A new genus of Leguminosae. *In* Jour. Wash. Acad. Sci. 10: 432,433. 1920.

45. ——and MORSE, W. J. Five oriental species of beans. U. S. Dept. Agr. Bul. 119: 1–32, pls. 7. 1914.

46. ————. and MORSE, W. J. The soy bean; history, varieties, and field studies. U. S. Dept. Agr., Bur. Plant Indus. Bul. 197: 1–84, pls. 8. 1910.

47. ———— . and TRACY, S. M. The Florida velvet bean and related plants. U. S. Dept. Agr., Bur. Plant Indus. Bul. 179: 1–26, pls. 7. 1910.

48. SCHULZ, O. E. A monograph of the genus Melilotus. *In* Bot. Jahrb. (Engler), 29: 660–735, pls. 3. 1901.

49. SCOFIELD, C. S. The botanical history and classification of alfalfa. U. S. Dept. Agr., Bur. Plant Indus. Bul. 131: 11–19, figs. 2. 1908.

50. SERINGE, N. C. Monographie des céréales de la Suisse. 244 p., pl. 1. 1819.

51. SHAW, J. K. Leaf characters of apple varieties. Massachusetts Sta. Bul. 208: 21–31, fig. 1, pls. 13. 1922.

52. STUART, WM. Group classification and varietal descriptions of some American potatoes. U. S. Dept. Agr. Bul. 176: 1–56, pls. 19. 1915.

53. SWINGLE, WALTER T. Citrus ichangensis, a promising, hardy, new species from southwestern China and Assam. *In* Jour. Agr. Research 1: 1–14. pl. 1. 1913.

54. ——and KELLERMAN, MAUDE. Citropsis, a new tropical African genus allied to citrus. *In* Jour. Agr. Research 2: 419–436. 1914.

55. SWINGLE, WALTER T. Eremocitrus, a new genus of hardy drouth-resistant citrous fruits from Australia. *In* Jour. Agr. Research 2: 85–100, pl. 1. 1914.

56. TODD, S. E. The American wheat culturist. 432 p., figs. 80, New York. 1868.

57. TRACY, W. W. American varieties of garden beans. U. S. Dept. Agr., Bur. Plant Indus. Bul. 109: 1–173, pls. 24. 1907.

58. TRACY, W. W., Jr. American varieties of lettuce. U. S. Dept. Agr., Bur. Plant Indus. Bul. 69: 1–103, pls. 27. 1904.
59. WIGGANS, ROY GLEN. A classification of the cultivated varieties of barley. Cornell Univ. Agr. Exp. Sta. Mem. 46: 365–456, figs. 22, pls. 5. 1921.
60. WIGHT, W. F. The history of the cowpea and its introduction into America. U. S. Dept. Agr., Bur. Plant Indus. Bul. 102: 43–59, Part VI. 1907.
61. ————. Native American species of prunus. U. S. Dept. Agr. Bul. 179: 1–75, figs. 4, pls. 13. 1915.
62. WILKINS, F. S. Hubam clover. Ia. Agr. Exp. Sta. Circ. 76: 1–16, figs. 7. 1922.
63. WILLARD, S. D., and BAILEY, L. H. Notes upon plums for western New York. New York Cornell Sta. Bul. 131: 169–195, figs. 12. 1897.

1b. TAXONOMY AND MYCOLOGY[1]

C. L. SHEAR[2]

This subject may not appear at first thought to have any very important relation to agronomy. However, it is not difficult to show that the taxonomy of the fungi has close relations to many of the economic problems connected with agriculture and horticulture and that everyone who has anything to do with fungi in any of their scientific or economic relations should realize the importance of this subject. It is also desirable, in these days of extreme specialization, to stop occasionally to consider more carefully the interrelations of the different branches of botanical science, both pure and applied.

The fundamental meaning of the word taxonomy is, of course, orderly arrangement. To the pre-Darwinian scientists, it meant an attempt to discover, describe and arrange living organisms according to the supposed order of special creation, the belief being that each species was created separately by omnipotent edict and was clearly distinct from all other species. Since the general acceptance by biologists of the origin of living organisms by evolution and their descent by natural processes from more ancient forms, taxonomy has come to have a very different significance and outlook. The present ideal and aim of taxonomy is to distinguish and describe the various groups of living organsims, and to discover and express in a systematic and orderly manner their natural relationships; in other words, to determine the phylogeny of the groups. In order to approximate this end, it should need but little argument to show that there is scarcely

[1]Paper read as a part of the symposium on "Research Fundamental to the Solving of Crop-plant Problems," at the meeting of the Society held in Cincinnati, Ohio, December 28, 1923.

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any information available or obtainable in regard to plants and plant life that has not a more or less direct bearing upon taxonomy. It naturally follows, therefore, that the qualifications for successful taxonomic work are very broad, and that the taxonomist should be able to avail himself of the knowledge acquired not only by morphologists but also by cytologists, physiologists, ecologists, and anatomists. Morphology has usually been regarded as the foundation of taxonomy. In recent years, however, there has been a tendency to base segregation of species also on physiological characters. This, as we shall attempt to show later, is not a satisfactory method of segregating groups of specific rank.

Coming now to the particular branch of the subject which I have been asked to discuss, i. e., taxonomy of fungi, I shall attempt to indicate some of its relations to economic botany and to all those workers with plants who come in contact with fungi in any of their investigations. The taxonomist should provide the identification of any fungus to which one may have occasion to refer, and also a name which will be recognized by the mycologists and pathologists of the world, and the application of which will be certain, i. e., a name which will not signify different things to different people or to people in different places, as is now frequently the case. The name should also have stability, i. e., it should not be changed later, so as to require the learning of a new name for the same plant, except for very weighty and important reasons. It is self-evident that, unless every one uses the same name for the same plant, and the same technical terms, error and confusion rather than truth and clarity, must result.

Pathologists, physiologists, and geneticists frequently find it necessary to deal with fungi, and, unless they know with certainty the organisms with which they are working and have names for them by which they are clearly and definitely known to others, there can be no application or coordination of the facts or results of their work. Many cases illustrating this might be cited from recent literature. Physiological investigators in particular frequently carry out elaborate experiments with fungi, to which they apply names which have no well-established or definite application, and which it is impossible for other investigators to identify with certainty. Their results, therefore, cannot be verified or coordinated with those of other workers who may have nominally used the same organism, but really did use something quite different. This is frequently true also of the work of geneticists and pathologists who refer, by uncertain names, to organisms with which they are dealing, so that

their colleagues, or future workers, can not determine with any certainty what they really had or verify their results.

In this connection, it is necessary to admit that, in the present state of knowledge of the fungi, and in the more or less chaotic condition of our nomenclature, it is in many instances impossible to name an organism with the certainty that this name will be correctly understood and applied by other workers. It is, therefore, necessary at present that all investigators who are working with particular fungi should describe and illustrate in detail the organisms with which they deal, and also deposit specimens, or cultures, or both, in the principal mycological herbaria of the world, in order that other workers may ascertain with certainty just what organism they used.

The recognition of this deplorable condition of affairs in mycological taxonomy and nomenclature should elicit the interest and cooperation of all groups of botanists in an attempt to improve these conditions as soon as possible.

At present, taxonomy is largely neglected and left to the inexperienced and incompetent. It is no wonder that it is in disrepute, when so-called "new" genera and species are named and imperfectly described in large numbers by those who have no conception of the qualifications of a taxonomist, and have very scanty knowledge of the species and genera already described.

It is easier to indicate what mycological taxonomy could and should do for pure and applied botany, than to point out what it has done or is doing. Some of the assistance which it should render to pathologists, physiologists, ecologists, and geneticists may be briefly indicated.

The relation of mycology to plant pathology is so intimate that it has been and still is difficult to separate the two. Since the majority of plant diseases are due to parasitic fungi, phytopathology consists chiefly of physiological mycology, and, in Europe, plant pathological work is frequently termed economic mycology. Hence, the plant pathologist should have a broad general knowledge of mycology and since, in most instances, he cannot devote the necessary time and study to the taxonomy of the organism with which he deals, he should be able to obtain from the systematic mycologist the correct name and synonomy of the fungus with which he is working. Otherwise, his work cannot be correctly interpreted by other investigators and may lead to serious misunderstanding.

The great importance of an exact knowledge of the identity and synonymy of fungi is especially emphasized in connection with the occurrence and distribution of serious plant parasites; such, for

example, as the chestnut blight fungus, the white pine blister rust and the citrus canker organism and others. Until it was demonstrated by taxonomic investigations that the chestnut blight fungus, *Endothia parasitica*, was a different species from any heretofore found in this country; and that it was also different from any species occurring in Europe; but that it was identical with a fungus occurring in China and Japan, no one was able to understand its distribution and behavior, and to tell in what direction to look for chestnut trees which were most likely to be resistant or immune to the disease and to take steps to avoid its introduction into other countries.

In this connection, attention should be called to the great importance of a systematic knowledge of fungi in connection with quarantine, inspection and other efforts to prevent the introduction of dangerous parasites into different countries. In order to attack these problems intelligently, it is necessary to know what species of fungi occur in each country, and also to know their synonymy. Otherwise, a very serious parasite might be introduced under a mistaken name, or under the supposition that it is already present in the country. Some of our most serious fungus diseases and pests have been introduced from the Orient and from a knowledge of the close relationship of the flora of some parts of that region to that of the eastern United States, one is justified in the belief that there are many fungus parasites there which have as great potentiality for damage to American crops and forests as those which have been introduced already. Hence, it is of the greatest importance to agriculture and forestry that a thorough survey of the diseases and fungi of that part of the world be made as soon as possible, in order to secure the information necessary to protect American crops as far as practicable from other devastating epidemics of plant disease.

The information which has just been mentioned in connection with the work of pathologists is equally, if not more, important in connection with ecological work with the fungi. Unless the fungi in different localities and regions are accurately determined and correctly named, there can be no conclusions of any value drawn from a study and comparison of such fungus floras as to distribution, occurrence, or other ecological relations.

In the case of the investigations of geneticists and physiologists, still more accurate and exact data in regard to the taxonomy and relationships of the organisms investigated is necessary. This leads to a consideration of a phase of the subject which is perhaps as well discussed here as elsewhere.

The taxonomy of fungi presents some rather distinct problems and

difficulties which are not met with in the taxonomy of flowering plants. It has been shown frequently in recent years that fungi which apparently show the same morphological characters, so far as our present knowledge goes, may show quite different physiological characters when tested as to pathogenicity or reaction to different culture media, temperature, moisture, or other environmental or nutritive conditions. These physiological peculiarities are apparently, in many cases at least, of a constant and permanent character, and are frequently of much importance in connection with pathological and physiological investigations, and it is necessary to designate them in some way. The recognition of these facts seems to demonstrate the need of two categories of names.

First; a name is needed for the general purposes of mycologists, economic botanists, and others who have no very special interset in fungi. This classification should be based primarily upon morphological characters which can be distinguished with reasonable certainty by ordinary macroscopic and microscopic examination. In order to avoid confusion, the term "species" should be applied only to such groups of individuals as can be distinguished by morphological characters. This is the way in which the term has been rather consistently used, from Linnaeus' time to the present day. It has been suggested however, that the term species should be redefined and applied to so-called elementary species, or races, or strains, which have been found to exist among flowering plants as well as fungi. There seems to be nothing to be gained, and a great deal to be lost, by attempting to apply a well-established and well-understood term like this to an entirely different thing.

Second; for the groups of organisms which are characterized by physiological differences only, and which can be determined only by careful inoculation or cultural studies, a special nomenclature is needed. Various plans and forms of designation for such groups have been suggested, but none generally accepted and adopted. After having considered this subject rather carefully, as well as the various proposals which have been offered, I believe that the following will meet the requirements of accuracy, simplicity and convenience in the naming of varieties and races, or strains, of fungi. It is now recognized that there are different degrees of physiological differences in these organisms, and it is difficult to say whether it is practicable or desirable to try to distinguish all such by particular names or symbols. I am inclined to believe that, for present purposes, two categories should be sufficient; variety, and race or strain. Since it is desirable, however, to recognize morpho-

logical varieties as well as physiological varieties, these two categories of varieties might be kept separate without difficulty by adding the abbreviation Vp. or P., after the trinomial to indicate the physiological variety. For strains of these varieties which show distinct host or other physiological reactions, arabic numerals would be simplest.

Take for example, the stem rust of wheat, the various strains,[3] or so-called "biologic forms," might be designated as follows: *Puccinia graminis tritici*^{1}, *Puccinia graminis tritici*^{2}, etc. If it is necessary to indicate still greater differentiation letters may be used, e. g., *Puccinia graminis tritici* a.

To express or to make intelligible and useful any system of taxonomy, there must be some form of nomenclature. The essential features of nomenclature are accuracy, uniformity, stability, and convenience. By accuracy, is meant the correct and exact use of a name for a particular organism or group of organisms, and not necessarily descriptive accuracy as to the literal meaning of the words composing the name. Accuracy in the application of a name is of fundamental importance, as there should be no uncertainty as to the organism or group of organisms to which any particular binomial applies. In order to accomplish this, it is absolutely necessary to have available something more than descriptions or illustrations for use in identification, even though these be in detail and exact; as there is always more or less difficulty and danger of error in determining plants from descriptions and illustrations. It is, therefore, necessary, in order to apply a name to a specific organism and to be as certain as possible that it is correctly applied, that there be available for comparison type or authentic material of the plant named. In order to make this possible, all systematic botanists who are describing new genera or species of plants should deposit portions of the material upon which the descriptions are based in several large and accessable herbaria in different parts of the world, so that other taxonomists may be able to compare and determine their collections with reasonable certainty. The practice of basing descriptions and names of so-called new species upon a single specimen, or upon a very small

[3]In this connection the following resolution was unanimously adopted on December 31, 1923, by the American Phytopathological Society at its Cincinnati meeting, after a full discussion of the subject: "It is the sense of this meeting that we continue to recognize species on morphological grounds and that if we recognize varieties in fungi we recognize them on morphological grounds; that we designate the entities which are recognized by physiological specialization as physiological races and that we recognize one category of physiological specialization and that scientific names be not attached to these except where historical precedent or dire necessity requires."

quantity of poor material, should be avoided and disapproved by all who are interested in taxonomy or in the true progress of science. In the future, names based on scanty or poor material, specimens of which are not available or readily accessable in several herbaria, should not be entitled to recognition or adoption, except perhaps in special cases where it is shown that the advancement of science makes this desirable.

Scientists, least of all, can offer any justification for publishing matter which will impede rather than advance science.

Uniformity in nomenclature or in the application of names can only be attained by the general adoption and use of the same name by all the botanists. Notwithstanding the many efforts which have been made during the past hundred years to formulate rules and regulations for the purpose of securing uniformity, this desirable end is far from having been attained. There is at present little uniformity, and no general agreement as to how such an end is to be reached. As a result of the failure thus far to secure the desired end through past or present plans, it may be necessary to adopt some other method. In this connection it may be proper to ask why past efforts have failed. The majority of botanists and others who need to use scientific names, with the exception of the few special students of systematic botany, regard convenience and stability as of fundamental importance in nomenclature. It would appear that they are justified in their position and also that a satisfactory degree of convenience and stability can be secured without sacrificing any of the other essentials. The morphologist, physiologist, ecologist, cytologist or anatomist having been taught, for example, that *Agaricus campestris* signifies the common edible mushroom, does not care to discard this name and to be required to learn to recognize or refer to it under some entirely different binomial. The specialist in systematic mycology cannot justify himself in attempting to displace such a well-known name without giving really important and satisfactory reasons for so doing. This raises the question whether the reasons which have heretofore been given for the multitudinous changes of botanical names are sufficient to justify the time and trouble caused thereby. In any case, the proposed end has not been attained and this would seem to be the final criterion. From a purely academic, or logical, point of view, "priority of publication" may be maintained as the so-called fundamental principle of nomenclature; but when practical considerations, such as convenience, uniformity, usefulness, and the best interests of botany and the advancement of science are onsidered, all other considerations are entirely outweighed. The

principle of priority has been thoroughly tried and found wanting. As a result of over thirty years study, observation, and experience in this subject, I am convinced that it is impracticable and should be abandoned as a fundamental consideration.

If priority as a fundamental principle is to be abandoned in the selection of botanical names, it will, of course, be asked immediately what basis is left? My answer is usage. The immediate response to this will be, of course, that usage is too uncertain and indefinite and can not be satisfactorily determined or defined. In reply I would say that I believe that it could be satisfactorily settled for all practical purposes, so far as the fungi are concerned, by a representative and competent commission of expert mycologists. This commission could decide what, in their judgment, is the best usage in the application of generic and specific names, and assign to each genus a type species, and to each species a particular specimen or specimens which would fix, for all future time, the primary application of these names without special reference to their synonymy or earlier use.

Questions of synonymy are important to taxonomists, and frequently to other specialists, and should be thoroughly worked out by monographers as rapidly as possible. The discovery, however, of an older specific or generic name in the synonymy of any species should not justify the changing of any name which is well known and has been typified. I am thoroughly convinced, as a result of experience, that the time and labor involved in attempting to determine fully the synonymy of all the species of fungi (there being named at present between 80,000 and 100,000 so-called "species") before being able to determine what name should be used and in persuading mycologists, let alone others, to adopt these strange names, is so great as to be absolutely unjustifiable and impracticable. To attempt it would mean a continuous state of confusion and change in the names of fungi for centuries to come. I believe that a thoroughly satisfactory system of names could be selected and adopted on the basis above suggested, with the least loss of time, labor, and inconvenience on the part of mycologists, as well as of all others who need to use Latin names.

The plan which I have proposed is in reality only an attempt to secure in a simple and unprejudiced manner what was the supposed purpose of the list of *nomena conservanda* of the Vienna congress. The trouble with the Vienna list was that it did not represent international usage and was not carefully prepared and considered by a competent body and did not provide for fixing the application of the names by assigning particular type species and specimens. Without

fixing the names chosen by the assignments of types there will still be little hope of attaining any satisfactory degree of uniformity or stability in the names of fungi.

Of course, it goes without saying that systematic botanists will never agree entirely as to the delimitation of species and genera; since, in the present state of knowledge, these are largely mental concepts and, therefore, necessarily differ according to the experience and mental characteristics of different taxonomists. I believe, however, that species and genera do exist, and that when sufficiently thorough and extensive field studies and abundant collections of fungi have been made, it will be possible to segregate these groups with considerable certainty; but, if species are described on the basis of a small scrap of a single individual, or of only one or two individuals, the author's idea of the species must necessarily be largely a mental concept. If, however, new names are based (as they should be) upon a broad field and herbarium study of many individuals, there is the possibility of giving a fair description of the characters of the group of individuals constituting the species. If descriptive mycology is to be regarded as a sport, as it apparently is by some persons, it should at least be more largely an *outdoor* sport.

The difficulties in the taxonomy of the fungi are much greater than those connected with the taxonomy of flowering plants. This is due not only to their vast number, small size, and microscopic characters; but also to the fact that most of them are dimorphic or pleomorphic; i. e., they produce two or more forms of fructification during their life history. Therefore, until the life history of each species is known, and its different spore forms described, it is impossible to determine its identity or relationship with any degree of satisfaction. Consequently it will be necessary, for a long time to come, to have a dual or triple system of nomenclature for many species, i. e., a separate binomial name for the conidial stage, the pycnial stage, and the perfect stage, as the connection between these stages must be determined by pure culture studies before all the stages can be combined under one name.

Having indicated in this imperfect way some of the vast problems and difficulties which confront the taxonomist in mycology, I trust that I have justified my attempt to enlist your interest and support in the advancement of this subject, in order that it may be pursued and developed in such a manner as to be of the greatest service to science in general, as well as to economic botany and agriculture. If science is to make the rapid progress which it should make and to give mankind the great benefits to which it is justly entitled, it must be through

greater coöperation, more disinterested service, and greater breadth of vision and interest among its devotees throughout the world.

APPENDIX

The following mycological subjects are of fundamental importance to plant pathology as well as to taxonomy and other phases of botanical investigation and are greatly in need of study:

Life history studies of all *ascomycetes* which cause or are associated with plant disease.

Monographic studies of the various genera of pathogenic fungi and the determination of their life histories and geographic distribution. The following genera may be suggested: *Pythium*, *Mucor*, *Fusarium*, *Gnomonia*, *Glomerella*, *Diaporthe*, *Pleospora*, *Mycosphaerella*, *Physalospora*, and *Botryosphaeria*. There are, however, many others of perhaps equal importance.

There are still many rusts whose life histories need to be discovered.

A thorough study of entomogenous fungi is also needed, as such work may lead to practical results in the control of insect pests.

Thorough taxonomic and life history studies of the fungous parasites of man and the lower animals are of great importance and much needed.

2. MORPHOLOGY[1]

R. A. OAKLEY[2]

After making a careful study of agronomists and their work, one is forced to the conclusion that there is a lack of appreciation of the need for more critical botanical studies, if problems relating to the culture of our crop-plants are to be solved most completely and advantageously. Frankly, the implication this conclusion carries with it is that agronomists as a group are not highly qualified botanists. If they had better botanical training, they would have greater predilections for botanical investigations, and the results would be evidenced in their work. There is much to be said with regard to the weaknesses in the teaching of botany in the undergraduate courses, in the undergraduate curricula in our agricultural colleges, and in the text books. These have a large share of responsibility for the agronomist's deficiency in botanical training and viewpoint. Their discussion, however, is somewhat beside the present subject. Certainly it is impossible to go back and correct the pedagogical faults of five or ten or twenty years ago; but it would appear quite profitable to try to enthuse agronomists with the merits of botanical research as a fundamental aid to them in their work.

It would be difficult indeed to evaluate fairly the relative importance to the subject of agronomy of the application of the various branches of botany. These branches are so closely interrelated as to make a clear cut separate evaluation of each them nearly impossible. However, it is evident that the application of any one of them is helpful. In the field of agronomy, as elsewhere in science, there is a distinct need for any agency that offers promise of help in the solution of the problems that confront the investigator. It is intended here to point out some ways in which research in morphology may be helpful, not only in a constructive way by suggesting new methods, but also by upsetting erroneous conclusions without going so far as to suggest other conclusions or new methods to replace old ones that it may prove faulty. The help derived from it may be immediate, potential, or even quite remote, but the knowledge gained is an advantage in itself, in that it fosters an inquisitive spirit. Possibly, as good a way as any to show the fundamental importance of morphological research to the solution of crop-plant problems, is to cite

[1]Paper read as a part of the symposium on "Research Fundamental to the Solving of Crop-plant Problems," at the meeting of the Society held in Cincinnati, Ohio, December 28, 1923.

[2]Agronomist, Forage-crop Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C.

specific advantages that may be expected from it. In doing so, no attempt will be made to arrange them in the order of their importance or to mention all the advantages that are well worth considering. So far as possible, the advantages cited will be accompanied by specific illustrations, taken from the results of relatively recent studies. It is hoped that these illustrations will arouse such interest that the investigator who hears or reads them will be encouraged to go out and start investigations of his own. The writer asks pardon for confining his choice of illustrations largely to forage crops and turf-forming grasses, but it is with these plants that he has worked and naturally is most familiar, and, after all, as Kipling says, "The things you learn from the yellow and black help you a lot with the white."

The study of the form and structure of crop-plants and their organs, and the development of the whole individual plant and its parts, is one which every true agronomist conducts, either by approved botanical methods, or in a casual offhand way. Casual observations are useful, but it is the critical studies that are needed. If some botanists had substituted the critical for the casual in their methods of study, text books and other botanical publications would be vastly more useful to agronomists than they are today.

Botanists have said that one of the most important advantages in morphological study lies in the fact that by means of it the variously formed parts of even the most highly differentiated plants may be traced back to the few primitive forms; furthermore, that the relationship of one higher plant to another is clearly shown by morphological study. But this leads to the field of taxonomy, which, while clearly within the bounds of morphology, has been or will be treated fully in this program by other speakers.

A critical study of cultural methods as they are related to crop production makes up a large part of the agronomist's work. But, obviously, cultural methods for any crop-plant cannot be well founded without a detailed knowledge of the form of the plant and the development of its parts. An excellent example of what is meant may be found in the case of perennial grasses, particularly the fine-turf-producing grasses. In the case of the latter, turf may be regarded as the crop, the ultimate product. There are probably more perfectly senseless, extravagant, or even harmful, cultural methods employed in the growing of fine turf than in the cultivation of any one of the tilled crop plants. This condition exists, regardless of the fact that fine-turf production has been practiced for centuries. The outstanding reason is found in the misunderstanding of the nature and

development of the roots of perennial grass plants. Briefly, the majority of those who are engaged in turf-growing think of grass roots as being perennial, as are roots of alfalfa or oak trees; whereas they are strictly annual. This erroneous supposition has led to absurd attempts to encourage deep root growth, and incidentally deep feeding, with the view that if the roots can be made to develop at a considerable depth they will remain there indefinitely and will be only slightly affected by the conditions of moisture, plant food, and other factors of the environment which exists at or near the surface of the soil. This in turn has led to faulty and wasteful practices in the so-called "making of soil" (where this is done artificially), in watering, in fertilizing, and in rolling and spiking, or scarifying, to bring about what the layman refers to as deep aeration. Through research in morphology, the nature and development of roots of perennial grasses became known, and, as a result, real improvements are being made in methods of culture. In no other way could this have been accomplished.

Again, a few years ago there was considerable agitation in favor of transplanting alfalfa in hills or rows. Many small areas were planted in this way. In some cases, very satisfactory stands were obtained; in others, the plants behaved in a peculiar manner. The crowns pushed out of the soil and no amount of cultivation or attention could prevent them from doing so. Studies of root development showed clearly that the tap root of an alfalfa plant is easily modified by environmental conditions. They also showed clearly the method that it is necessary to follow if transplanting is to be done with uniform success. The transplanting of alfalfa has proved an economic failure; but the knowledge gained from the study of the morphology of the tap root has been exceedingly useful in many ways in practical alfalfa culture.

In the culture of crop plants the agronomist often finds himself in much the same situation as the physician who has a patient with an obscure disease. He is obliged to treat symptoms. There is too much treating of symptoms in agronomy. Morphological research will do much to correct this. As an example of what is meant by the treating of symptoms, turn again to the result of research in fine-turf production. Red fescue is a good fine-turf grass for certain conditions in northern states. It is used to a considerable extent on golf courses, particularly on putting greens. The requirements of the game of golf are exacting. Putting greens must have turf of fine texture and of uniform surface. To accomplish this, close cutting is necessary and, with the modern putting green mower, it is possible

literally to shave the grass down to the very surface of the ground. Because of the urge of the players for fast greens, the greenkeeper is inclined almost unknowingly to cut the grass exceedingly close. The bent grasses thrive under this treatment, but red fescue does not. The latter will withstand close cutting for a time and then in the language of the green keeper it "commences to go back." The common treatment has been to apply a topdressing of compost, or some quick acting nitrogenous fertilizer, or both. Careful studies have revealed the cause of the trouble. It is due to a peculiar morphological character of the red fescue plant. At the crown or base of each turf-grass plant, regardless of species, there is a short stem or axis made up of a number of unelongate internodes from which new shoots, with leaves, are continuously developing. In the bents and certain other species, these shoots may come from the very lowest buds. In the case of red fescue, the shoots that make the turf are produced from the upper part of the basal axis. Consequently, when the top of the basal axis is cut off by the mower few shoots develop from the lower nodes and the turf becomes thin. Topdressing and fertilizing to improve such a turf is merely treating symptoms. What is needed is to raise the mower so that the basal axis of the plant is not injured. "The life of an organism," says Strasburger, "is thus only possible when its construction is in agreement with its environment and it is adapted to the conditions of life." Morphological studies have shown clearly why it is that red fescue turf cannot be cut as closely as can bent grass turf, and have suggested the treatment that is the most helpful when the turf commences to get thin.

The explanation of the resistance of a plant to its pests is sometimes found in morphological characters, and if the plant culturist bears this point in mind and studies his plants carefully, he may gain knowledge that will aid him in breeding for resistance and in the treatment of diseases and injury. For example, brown patch (*Rhizoctonia solani*), a fungous disease of grasses, frequently is so rampant as to injure or even destroy large areas of lawn or other fine turf in a single night. Certain grasses, such as Kentucky bluegrass, are almost, if not completely, immune to it. The reason is not known. It is probably due to a physiological characteristic. The bent grasses are all susceptible to brown patch, but certain strains of the bents, especially of creeping bent, show a resistance to it to the degree that they are usually only lightly attacked and recover quickly from an attack, if favorable conditions are provided. Research has shown the reason for the relatively quick recovery of these strains and suggests how the recovery can be hastened. The most resistant strains of the bents, so

far as known, produce an abundance of stolons, or rooting stems having numerous nodes with short internodes. Each node bears a bud capable, under proper conditions, of producing a grass plant. Under the conditions requisite for the making of fine turf, the stolons are kept from appearing on the surface by close mowing and the application of loam-like compost. Although not apparent to casual observation, the stolons nevertheless are always present in considerable abundance. Brown patch attacks grass on the surface, in many cases killing the leaves and crowns. The roots, of course, cannot live long with the green parts destroyed, but since there are an abundance of soil-covered stolons bearing buds ready (if given a chance) to produce shoots, it is easily seen how recovery may be brought about. With a knowledge of this fact as a basis upon which to work, the agronomist, or plant culturist, or greenkeeper, or gardener, or whatever he may be called, prescribes and administers the treatment. It is simple. A light compost dressing to which is added a small proportion of sulphate of ammonia or of any quick-acting nitrogenous fertilizer, used with precaution to prevent burning, then liberal irrigation is all that is called for. It is not a case of bringing the dead back to life, but simply of stimulating the dormant into action.

Agronomists who do not know their plants intimately frequently fall into errors by concluding that cultural methods for closely related plants should be the same or similar when the plants are used for the same or a similar purpose. A few years ago the Forest Service of the United States Department of Agriculture issued a publication setting forth the merits of different types of range management on grazing lands in the Forest Reserves of the west. Among the systems of management, one was especially recommended. The principal feature of this system involves a systematic deferring of grazing, so that the range plants may be given an opportunity to mature seed and thereby perpetuate themselves more abundantly. This system was recommended for the dry range, where the vegetation is of the bunch grass type. Yet, following the publication of the Forest Service pronouncement on range management, there came bulletins and articles advocating the adoption of the practice of deferred grazing for the pastures of the northeastern states. Had the authors fully understood that bunch grasses are morphologically quite different from true turf grasses, they would have known that the pasture grasses of the humid northeast not only do not need a period of rest in which to mature seed, but are positively deterred from making their best development for pasturage if allowed to produce seed. Mor-

phological studies go far toward explaining why this is true. The turf-forming grasses of the humid sections depend upon stolons, or rootstocks, or both, for a continuation of their existence. Seed production deters the development of these organs. Incidentally close grazing benefits them; allowing them to produce seed causes them to languish.

During a part of his term, President Woodrow Wilson kept sheep on the White House lawn. A western congressman, probably not entirely in sympathy with the administration, voiced a protest. "Any damn fool," he said, "knows that sheep are hell on grass;" but he did not know that, as Ingalls once said, "all grass is not bluegrass."

Closely allied to this type of error is that of assuming that very closely related species are practically interchangeable in the matter of their utilization. Of course, in many cases they are; but in certain cases, where they are not, there has been for a long time, and is still, a persistent tendency to so regard them. Few persons will deny that Kentucky bluegrass is without an equal as a lawn grass for the northern part of the United States, where there is sufficient moisture for its growth. But as a lawn grass, its sister species, Canada bluegrass, cannot be regarded even favorably. There are, however, thousands of pounds of seed of Canada bluegrass sown annually on lawns, principally in mixtures. Seedsmen are not alone responsible for this. Gardeners and others have gone on for years trying to make a lawn grass out of a species that is morphologically quite unsuited for the purpose. While many agronomists and others have long known Canada bluegrass is not a suitable lawn grass, it is only within the last year or two that the real reason was discovered. In each true turf-forming species of grass the internodes of the basal axis remain unelongated, or at most they elongate but slightly. Therefore, the new shoots that develop from time to time do so at the very surface of the ground. Thus, a mat is formed, if the grass is cut frequently, and no stems or culms are erected. The basal axis of Kentucky bluegrass plants behave in this way. But in the case of Canada blue grass the behavior is different. When the plants of this species pass the seedling stage, the internodes of the basal axis commence to elongate. Mowing cuts off the shoots as they are pushed up by the elongating basal axis, and it is impossible, therefore, for a mat of leaves to form on the surface and to make turf. There results, after a few months of growth and frequent mowings, a stubble with only a scant number of leaves present. The grass makes sod but not turf. A comparable case is that of redtop and the bents. The latter are most excellent

turf-forming grasses. Redtop is useful only in the seedling stage. In this stage it is very useful in conjunction with Kentucky bluegrass. Again, there is a morphological reason, which is now very generally known.

There is at least one subject in agriculture upon which there is unanimous agreement. That is that there is no royal road to success in the eradication of weeds. Morphological studies, however, have done much to assist in the development of practical methods of eradication or control. If given an opportunity, they will do much more. Cates has pointed out the possibilities in the case of Johnson grass.

Analogous to the control of weeds is the management of the crop plant that has weedy or aggressive tendencies. Such a one is *Bromus inermis*. The course of development in this grass is such that the rhizomes are produced in the spring from the shoots that live through the winter. The summer crop of herbage is produced by the aerial shoots that come from the rhizomes. Late in the summer, buds on the nodes of the basal axis of the aerial shoots develop into shoots and these in turn carry on during the winter when the rhizomes become functionless. The weak spot in the life history of brome grass is during the development of these over-wintering shoots. This fact, therefore, may be taken advantage of when a change is to be made from brome grass to some other crop.

In his efforts to produce stocks of unmixed seed of selected strains of timothy, Morgan W. Evans of the office of Forage Crop Investigations, Bureau of Plant Industry, United States Department of Agriculture, found that a great majority of rogue plants which he thought had come from seed brought to the field by other means than intentional sowing came vegetatively from timothy plants that had previously been plowed under in midsummer. This was apparently the first time that the phenomenon of young timothy shoots offsetting from old plants by rooting stems had ever been observed To Evans, this observation was exceedingly valuable; since it put him in the way of using much simpler methods in keeping out volunteer timothy plants than would be necessitated if these plants were seedlings.

An adequate understanding of the functions of the various organs of the plant is impossible without a detailed knowledge of the form, structure, and development of these organs. Without such knowledge mistaken conclusions are sometimes drawn regarding their functions. Apparently, this has been done in the case of the so-called timothy "bulb." The enlarged internode at the base of the timothy culm,

commonly known as the "bulb," is very generally thought to function as a food-storage organ, from which the plant may draw needed food. Upon investigation, it was found that there is a general misunderstanding as to when the organ develops. It is commonly thought that it develops in the fall and is, therefore, available to assist the plant through the vicissitudes of winter. On the contrary, in the latitude of northern Ohio, this corm-like organ develops in May, or about that time, after the plant has passed through its period of greatest vicissitude and has made a good strong growth. Whether or not the clearing up of the life history of the timothy "bulb" will lead to anything of practical value remains to be seen, but it will add to the knowledge of the timothy plant and is therefore worth while.

Studies such as these, even though of remote practicability, help the agronomist by increasing his keenness of perception and accuracy of observation. They also enlarge his resourcefulness and make of him a better investigator. Furthermore, they will serve him in many other ways.

Not all the reactions of plants can be explained on morphological grounds. Agronomists have erred in concluding that certain phenomena are due directly to certain gross morphological characters. A decade ago, it was thought by many that the difference in winter hardiness between strains of alfalfa was due very largely to the degree of protection the plants give the resting buds during the winter. Inasmuch as hardy strains in general are characterized by crowns that are set well in the soil, and many of them have rhizome-like stems which bear buds from which aerial shoots are produced, it is easy to understand why winter hardiness was in a large measure attributed to the physical protection given the buds. But, actually it is something besides physical protection of the buds that makes an alfalfa plant winter hardy; for, when the crowns of plants of relatively tender varieties are well covered by soil or otherwise protected, the mortality due to severe winter weather is lessened but little. Winter hardiness in alfalfa varieties seems to be largely an inherent quality of the protoplasm. This illustration is not intended to lessen the regard for morphology but to bespeak due consideration for physiology.

Morphological studies that it would be profitable to make are almost without number. The field has merely been scratched. Botanists have avoided some of the more difficult problems. Hence, there is much in the field of morphological botany for the agronomist to do. What Percival has done for the wheat plant, and Evans for timothy, should be done by other agronomists for the plants with which they are working.

A word should be said here with regard to terminology. Better terms are needed for certain parts and characteristics of plants. Improvement in this line should be made at once. Agronomists should take a lesson from the medical profession. Doctors have a terminology of their own, highly technical it is true, but definite. Exactness in terminology lessens confusion.

A need for improved technique in the making of critical morphological studies is also apparent. For example, studies in the perennating habits of grasses and the development of the roots of perennial species doubtless would proceed much more rapidly if the technique were well worked out. Given the spirit to conduct investigations, good technique and better terminology, the agronomist would be better able to attack some of the hardest of economic crop-plant problems.

3. PLANT PHYSIOLOGY[1]

WM. CROCKER[2]

I feel that I can best present what I have to say about the relation of plant physiology to agronomy and other practical phases of plant production by discussing the following four topics: 1. history of the relation of plant physiology in the United States to plant production; 2. complexity of plant physiology problems in agronomy and some newer methods of attack; 3. necessity for a comprehensive all-sided attack on these problems; 4. contributions of agronomy and other applied lines to plant physiology.

1. HISTORY OF THE RELATION OF PLANT PHYSIOLOGY TO PLANT PRODUCTION

I believe that plant physiologists in America during the past forty years might have been many times more helpful to plant production and at the same time fully as productive scientifically had they gone to a different place to find their research problems. Until recently, plant physiologists in America were largely trained in the theoretical laboratories of Germany. These laboratories not only had little knowledge of, or sympathy for, the applied fields, but in many cases, they were antagonistic to them—drawing a sharp line between pure and applied science. These German plant physiology laboratories suffered another defect, that of over-specialization.

[1]Paper read as a part of the symposium on "Research Fundamental to the Solving of Crop-plant Problems," at the meeting of the Society held in Cincinnati, Ohio, December 28, 1923.

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They lacked chemistry and, in many cases, other phases of botany, such as anatomy and cytology, that are essential to the understanding of many physiological problems.

It was in these laboratories that the early American plant physiologists found their problems and got their training for solving these problems. The problems were highly theoretical and the technic for solving them very simple and superficial. Often, an American brought back with him the Geheimrats' problems in tropism and continued to work on these most difficult problems of plant physiology with simple and inadequate methods, while many problems of much greater scientific import, capable of solution and with the added virtue of large practical significance, remained untouched about him.

What has been said implies no lack of appreciation of the epoch-making nature of the work done by German plant physiologists from 1860 to the beginning of the war; but after all, this was only a beginning, a first step. Progress in the subject from now on, both scientific and practical, calls for more thorough-going and adequate methods as well as more comprehensive attacks on the problems.

Where could the early American plant physiologists have found their problems, if not from the German Geheimrat? The horticulturists, the agronomists, the market gardeners and back of these, the nurserymen, seedsmen and farmers, are good at suggesting problems for the plant physiologists. These are often very real problems, their actuality having been proved by their long and repeated interference with the progress of practical men.

A forlorn and disconsolate florist once approached me with the question, "How does illuminating gas effect carnations?" This was to him a very real problem, for he believed that through this injurious agent he had lost the accumulations of years. I accepted his estimate of the problem and my colleagues and I proceeded to study the effect of illuminating gas and its constituents upon plants. This work proved that ethylene is a remarkable substance, so far as its effects upon plants are concerned. It modifies the growth of some plants in dilutions as high as 1 part in 10,000,000 of air. The injurious effect of ethylene upon plants is frequently due to its great power to quicken development or to cause dormant cells or tissues to become active. Examples of this are the hastened development of abscission layers causing premature leaf and petal fall, the induced hyponasty causing flower closure and the gall formation on the root, stem or crown. Ethylene is proving to be one of the best forcing agents for plants. It is very effective in hastening the ripening of various

fruits as well as root development on cuttings. Doctor Luckhardt was induced by the remarkable effect of ethylene upon plants to study its effect upon animals and has thus given the world what is perhaps generally its best anaesthetic. All of this is to show that the old florist easily averaged up with the University professor in assigning a worth-while research problem, whether we desire scientific or practical results.

I know of a case where a plant physiology laboratory has the reputation for picking good fundamental problems which at the same time have large practical bearings. This reputation is largely a result of view point. It is maintained by this laboratory that a good plant physiology problem can contribute both to science and to practice. Because of this viewpoint, the research students, largely from agricultural colleges and experiment stations, have worked, as far as possible, on problems of importance in the several regions from which they came, rather than on problems peculiar to this laboratory. The laboratory largely furnished ideas on methods of attack and technic for handling fundamentally problems of the various states. Many more plant physiology laboratories of this sort are needed, both in private and state universities, but these laboratories need to be much better organized, manned and equipped than any we have up to date, so that in a steam shovel age we may not be doing things with hand shovel methods.

The head of a department of market gardening in one of our best agricultural colleges expressed it as his opinion that plant physiology has fully as much to contribute to plant production as has plant pathology. He then proceeded to inquire why plant physiology in the United States does not have an organization commensurate in size and aggressiveness with that of the pathologists. I have heard similar expressions from prominent men working in other phases of plant production. All this seems to indicate that plant physiology is falling short of rendering the great practical service that it should. I believe that I have mentioned above one of the important reasons for this and suggested a significant remedy, namely, let the plant physiologists seek their fundamental problems in connection with practice. There are other things, however, that need attention.

Today the worth-while problems in plant physiology are mostly very complex. They demand much expensive apparatus and equipment. They call for a great range of technic, involving several fields of chemistry and physics as well as other sciences. This means that marked success calls for large, well-equipped laboratories, manned by specialists with a variety of training. Until recently, pathological

technic was much more simple and did not demand such complex equipment. In its recent tendency toward a physiological attack it will meet the same complexity.

In spite of the need of well-equipped and manned centralized laboratories, the disposition in our agricultural institutions, including the United States Department of Agriculture, has been to distribute the young plant physiologists whom they employ out amongst the several divisions of plant production, without any connection with such a well-equipped and manned laboratory, where the appliances and methods of the science are in constant operation and where the extensive and diversified knowledge of the subject is the every day talk of the workers.

I judge that this symposium is not held to soothe each others feelings with softly uttered platitudes, as if we were holding a fully dressed-up meeting of a city woman's club. I judge on the other hand, that it is an attempt to better agronomy and the sciences fundamental to agronomy. This being the case, I want to say that it is the consensus of opinion of the plant physiologists of the United States that the United States Department of Agriculture and the large State agricultural colleges and Experiment Stations should have strong, well-manned, well-equipped plant physiology laboratories, and, that so far as practical, the plant physiology work in the various divisions should be done in cooperation with these laboratories.

If, in certain respects, plant physiology is in a bad way in the United States, perhaps nobody is so much to blame for it as the plant physiologists themselves. They have certainly lacked the aggressiveness and organization spirit of the plant pathologists, things that seem necessary to impress on the agricultural world the practical service they are able to render. Now this spirit of agressiveness and organization seems to be rising. It is about to give us the "Plant Physiology Society of America." But as we shall see later on, we may not be justified in unlimited enthusiasm for the formation of a new plant science group.

Perhaps agronomists and other groups who are in close touch with practice may help out here, by seizing upon this new aggressiveness of the plant physiologists and putting it at work on very important practical problems which, if properly attacked, will, at the same time, yield results of great scientific value. In an enthusiastic attack on these problems, the plant physiologists might lose some of their enthusiasm for mere organization. They have something the matter with them and don't seem to know what it is. If a science

or a scientific group had a conscience, I would believe that their conscience was hurting them for not having done their practical duty in the past.

2. COMPLEXITY OF PLANT PHYSIOLOGY PROBLEMS IN AGRONOMY AND SOME NEWER METHODS OF ATTACK

Physiological problems in agronomy are very complex. When viewed in one way, they appear hopelessly complex. There are many factors which affect the development of crop-plants. Each factor may exist in many degrees of intensity. All these factors in all degrees of intensity mean an infinite number of combinations. All these factors in combinations of several intensities mean an enormous number of combinations. This seems to be almost a hopeless number for experimental determination. Even with an enormous amount of equipment for accurate control of conditions—equipment that one will find very costly if he undertakes to have it produced—these problems appear staggering when viewed from this point.

Viewing these problems from another angle, however, there is more hope. There are several pieces of work that indicate that a number of different external conditions may produce similar internal conditions in the plant and these internal conditions, in turn, lead to similar developmental and other behavior. These pieces of work give hope that amid diversity of external conditions we may find unity in the internal effects produced. They also indicate that many principles of plant development may be learned by varying the external conditions rather broadly, quite aside from highly accurate control, and studying the effect of such variations at the same time upon the rate and course of development and upon the internal nutrient conditions. The combination of this method with very accurate control of external conditions, where of course, internal conditions and developmental features are both carefully studied, point the way to real advances in problems of plant development.

Let us now look at two cases where diverse external conditions bring about similar internal nutrient conditions, accompanied by similar developmental behavior and, later, one other case where a study of internal conditions throws at least some light on the mechanism by which an external factor determines growth behavior.

Reid is able to control the proportion of root and shoot development in cuttings of tomatoes and *Bryophyllum* by growing the plants in such condition as to give various proportions of carbohydrates and nitrogen in the cuttings. High carbohydrate content of the cuttings, with low nitrogen, favors root development; while high nitrogen with

low carbohydrates favors stem development. In these experiments, the proportions of carbohydrates and nitrogen in the cuttings were determined entirely by varying the nitrogen supply to the normally illuminated plants from which they were taken.

Dickson has found that wheat plants, which are grown near the minimum temperature for wheat growth have roots about four times the weight of the tops. This holds true whether the plants are taken in an early stage when they are largely nourished from the seed or at a much later stage when they are entirely independent of the food stored in the seed. Wheat plants which are grown near the maximum temperature for wheat growth have tops several times as heavy as the roots. This also holds whether the plants are taken in the early stage when still dependent upon the stored food of the seed or at a much later stage when entirely independent of the food stored in the seed. When the plants are grown at low temperatures, the growing regions have a high proportion of available carbohydrates and a low proportion of nitrogen. When grown at high temperatures, the reversed relations are true. The temperature seems to have its marked effect on proportion of root and top development by modifying the proportion of available carbohydrates and nitrogen.

In these two cases, two very different external factors, nitrogen supply and temperature, controlled a developmental factor, namely, proportion of roots and tops. In doing this, the two factors apparently worked through the same internal condition, proportion of two groups of nutrients.

Klebs, H. Fischer, and Kraus and Kraybill have all come to the conclusion that relative proportion and abundance of carbohydrates and nitrogen in higher plants is a very important factor in determining whether the plant shall be dominantly vegetative or shall be a balance between vegetative vigor and fruitfulness. The several workers used a considerable number of species of plants. They also modified the proportion of carbohydrates and nitrogen in the plants by varying three different external factors. Klebs varied the illumination; Fischer, the carbon dioxide content of the air; and Kraus and Kraybill, the amount of nitrate furnished the plant.[3]

[3]The fact that Kraus and Kraybill with their methods of experimentation produced plants extremely high in carbohydrates and low in nitrogen, plants showing little vegetative vigor and no fruiting, a condition not obtained by the other two workers with their methods of experimentation, does not modify the general agreement in the results and conclusions of the several workers. Likewise, the existence of secondary factors as necessary for the utilization of nitrate nitrogen does not alter the significance of the carbon-nitrogen ratio as an important internal developmental determiner. Two such secondary factors have been observed. Kraybill finds that in tomato plants nitrate nitrogen is not available for protein

Let us look at another illustration that shows how an examination of internal conditions throws light on development behavior. Seeds with dormant embryos are found to afterripen, or go through the preliminary changes necessary for germination, most rapidly in a germinator at 5° C. It is found that this temperature leads to the most rapid accumulation of soluble sugars, amino-acids and phospholipines—all building materials readily available for the formation of new tissues—and certain enzymes which are probably necessary catalysts for growth.

This matter of determining the internal conditions is very important; but it is not as simple in most cases as in the examples we have just cited. In these examples, the external conditions modified internal general nutrient relations which in turn were developmental determiners. On the other hand, where the external conditions act directly upon the protoplasmic machinery, the determination of the internal effect will be much more difficult, in most cases impossible, with the present methods available. It is possible even to determine the amounts and proportions of the nutrients in plants only by larger groups, such as reducing sugars, hydrolizable carbohydrates, insoluble proteins, etc. No methods are available for determining exactly the amounts of such things as individual sugars, amino-acids or proteins in the plant. There is great need of encouraging the adaptation and improvement of all sorts of chemical and physical methods for studying the composition and conditions of plant tissues. Most of these questions are quite beyond the methods that American plant physiologists learned in Germany twenty-five or thirty years ago.

In this connection, I wish to call attention to the difference between an external condition as an immediate response factor and an external condition as a development factor. Walster has illustrated this by the relation of temperature to the germination and early growth of wheat. According to Haberlandt's much-quoted data, the optimum for the germination of wheat is about 25° C. This merely means that the seeds germinate most quickly at that temperature. It is a quick response consideration rather than a development consideration. According to Gutzeit and others, only sickly plants of many small grains, giving low yields, are produced, if germination and early growth occur at temperatures above 20° C. The optimum temperature for the germination of seeds of small grains is 17° C, or lower, if maximum crop is desired. In this sense, optimum tempera-

synthesis even in the presence of an abundance of carbohydrates, if phosphates are deficient. Nightingale also finds that in several plants daily illumination exceeding a certain duration is necessary for the transformation of nitrates to insoluble nitrogen compounds.

ture for germination is a real developmental consideration. In practice, the time of sowing the small grains may involve this fact as a sort of unconscious acquisition of human experience. As the workers who were mentioned above point out, the small grains are favored rather than injured in later stages of their development by somewhat higher temperatures.

If one starts with a plant well below the "optimum" temperature and raises the temperature 10° C, there is an immediate increase in the growth rate of two to three fold. This does not mean that such an increased rate will be maintained throughout the life of the plant. The higher temperature may and generally does gradually bring about changes in the chemical make up, and perhaps other characters of the plant, that alter the rate of growth as well as the course of development.

Unfortunately, most of the experimentation in plant physiology up to date has been of the immediate response type. Such studies required only small control apparatus running for a short time. The really helpful plant physiology so far as agronomy is concerned is developmental physiology. Much of such work calls for large control apparatus running during the entire life of the plant. In such apparatus, it is desirable to have all conditions under control as far as possible; light (intensity, quality and duration), temperature, humidity, carbon dioxide concentration of the air as well as soil conditions. Such apparatus is expensive. It is probably a fair estimate that a chamber twenty-feet square will cost thirty thousand dollars for construction and interest returns from six times that amount for continuous operation. It is evident that such apparatus can not be installed at all of our plant science institutions or even at many of them. It might be well for the several plant science men interested in development problems to get together and work toward the equipment of three or four laboratories located in various parts of the country and provided with these controls. Problems demanding such equipment could then be taken to these laboratories for solution.

3. NECESSITY OF A COMPREHENSIVE ALL-SIDED ATTACK ON THESE PROBLEMS

Sometimes a local chemical change in plants is the very crux of the explanation of physiological behavior. This calls for microchemical studies. This is true of Eckerson's unpublished work on the effect of light on the light-inhibited seeds of *Phacelia* and *Nigella* and on the light-requiring seeds of *Gesneriaceae*. It is doubtful whether any other method can detect most of the changes produced in the coat of

these seeds by the combined actions of light and the iron salts stored there. Sometimes the very essence of a physiological explanation depends upon the general chemical constitution of the plant as determined by tissue analysis. This is true of the work of Kraus and Kraybill mentioned above. Again, anatomical characters often explain physiological behavior. Often all of these and other studies must be made in order to be sure of the reason for physiological behavior. I long ago concluded that plant physiology is not a science in itself but it is only a part, a phase, or a view-point, of the whole. Botany, or plant science in the broad sense, is the whole and all of the phases should develop in the closest relation to each other to insure fast and sure progress and to insure that no phase be given undue meaning.

Also, the scientific phases are benefitted by developing in close relation with practice. I have observed that scientific men are apt to be a little more careful of their conclusions when somebody's million dollars depend upon these conclusions than when the end of the work is the adornment of the pages of the Botanical Gazette or the American Journal of Botany. Then, too, the greater diversity of conditions met by men in immediate contact with practice, in contrast to the strict laboratory men, has a broadening and salubrious effect on the work of the latter.

This need of a cooperative all-sided attack on our present day complex scientific problems is well described in the following quotation from a little pamphlet issued by a committee of the American Chemical Society, entitled "The Future Independence and Progress of American Medicine in the Age of Chemistry:"

"When it became clear during the recent war that poisonous gas was to constitute an important munition, our country called to its service a great group of its ablest research chemists to provide means of defense and to solve those problems of production which would provide our field forces with an ample supply of this new weapon.

Not to the professional inventor nor to the accident of haphazard discovery was this grave responsibility assigned, but to the trained workers in systematic research. Nor were these men asked to undertake this vital work in the seclusion and isolation of their respective laboratories but they were assembled at the American University Experiment Station on the outskirts of the city of Washington, under one roof as it were, where by daily, nay hourly, conference, utmost speed could be secured in the solution of those problems on which the question of life and death so closely hung.

But these chemists found that they alone were inadequate for the task. To supplement their special skill and knowledge there were added to the staff pharmacologists and experimental pathologists.

Through the combined efforts of these groups, working in closest association and provided with ample facilities for research, results were accomplished

with a speed and certainty which amazed all. The paths to agencies for both defense and offense were clearly pointed out and large scale production quickly followed."

In spite of the need of getting together, the disposition of American botanists is to split up into separate societies. If the systematists, the morphologists and the cytologists should organize separate national societies, the picture of dissolution would be complete. The disposition of each phase of botany to form an independent society may have certain advantages, as well as evident disadvantages. It may give each group a self consciousness and agressiveness that will make for greater progress in several phases of the work.

It is possible that we can get the advantage of these special organizations and overcome the disadvantages in another way.

In spite of the disposition to form new national societies, at annual meetings the men who work in related sciences seem to be getting together in symposia and otherwise in a way to insure progress of plant science; but after all, it is not so important how we group ourselves or even how we behave here at these meetings, provided the working conditions in our laboratories at home are good. The alarming thing is the fact that the same disposition to disintegrate shows up in many of our big laboratories. In view of the present complexity of research problems in plant science, it would seem that surest progress will be guaranteed by strong departments of botany, constituted of all the phases of the subject, rather than by departments representing each phase. The several phases should not only be cooperating smoothly, with all phases within the department; but the botany department should be cooperating fully with applied lines such as horticulture, agronomy, soils and market gardening. Big industries are getting good team work in their research. The plant science groups with their greater idealism ought to do as well. It is time for laying aside temperament and little differences for the sake of big accomplishments.

I believe the best progress of agronomy is dependent upon the existence of such botany departments. Your own welfare might justify you in giving some attention to this and in exerting some pressure toward building up such departments. It is often very easy to get funds for immediately practical problems, but hard to get them for more fundamental work. Yet the latter may be the way to sure progress. This would justify you again in throwing your influence in favor of the strongly supported botany departments.

4. CONTRIBUTIONS OF AGRONOMY AND OTHER APPLIED LINES TO PLANT PHYSIOLOGY

The very fact that the agronomists have arranged this symposium shows that they think the several fields of botany have contributions to make to practice. For plant physiology, at least, I want to emphasize that this beneficial relation is reciprocal.

As one looks over the work done during the last two decades in the more practical lines, horticulture, agronomy, market gardening and especially plant pathology, he sees more and more tendency to turn to plant physiology. There are probably more plant physiologists now employed in these departments than in regular plant physiology laboratories. As time passes, the proportion promises to increase greatly.

One would be very defective in his knowledge of American contributions to plant physiology, if he neglected the contributions of these more practical lines. During this and following decades plant physiology will experience the same contributions from practical lines that animal physiology has experienced for several decades from research in medicine.

The thing that is most worrying plant physiologists in the United States today, and driving them to form a separate society, is the thing that promises to add much to their science; namely, the assimilation of plant physiologists by the more practical lines. I really do not know whether to be worried about this situation or to be cheered up by it. If strong laboratories of plant physiology existed as parts of good botany departments in most of our agricultural colleges and experiment stations—laboratories where the every day talk and practice are the latest knowledge and technic of the subject—I am sure I would be optimistic.

4. CYTOLOGY[1]

R. A. Harper[2]

I take it that our discussions are in the nature of program-making. While we hear much criticism in certain quarters of the tendency to spend overmuch time on elaborate planning, it is fairly obvious that, with the diversification of scientific effort, cooperative program-making is becoming increasingly necessary.

I may be permitted, perhaps, to sketch my own idea as to the relation of the particular field of study, cytology (which I am asked to represent) to the other fields of research which are to be presented. I may first note that when, years ago, the term began to have considerable vogue, doubt was expressed as to its use as quite unnecessary and likely to be misleading. That there could be a domain of cell science which was not either physiology, or morphology seemed then, and may still seem, to be a very incorrect idea. In a word, in my opinion, cytology is in reality cellular physiology, excluding developmental cellular morphology; since we know next to nothing of the evolution of cells from the non-cellular or inorganic world. I should define its scope more exactly by calling it general physiology dealing particularly with those cell processes which are common to all living things, both plant and animal; such as reproduction, growth, protein and carbohydrate metabolism, secretion and excretion as contrasted with transpiration, sap flow and the various tropisms of stems and roots, etc.; all of which are special functions of the higher vascular plants, as the functions of the circulatory, muscular, nervous and other systems as such belong to the special physiology of rather highly differentiated animals.

Perhaps the most obvious and the easiest field of fundamental research on crop plants is the study of the control of their diseases. The wonderful achievements in this field which have resulted from the discovery and use of insecticides and fungicides by modern spraying and dusting methods are recognized by scientist and layman alike, and we must never forget that much of the willingness of legislators, state and national, to vote further large sums of money for scientific study of the problems of crop plants is based on their direct knowledge of the successes that have been already achieved in the control of plant diseases. It would be hard to over-estimate the im-

[1]Paper read as a part of the symposium on "Research Fundamental to the Solving of Crop-plant Problems," at the meeting of the Society held in Cincinnati, Ohio, December 28, 1923.

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portance of the early successes in controlling grape mildew and black rot, for example, in making possible the tremendous expansion in all lines of agricultural research, which has come in the last quarter century. The further perfection of methods already known and the discovery of new and more effective methods of elimination of the wastage and destruction due to plant diseases is certainly one of the surest methods of alleviating the "distresses of the agricultural situation" as we are wont to call it.

The pernicious doctrine (which is now strenuously voiced in certain quarters) that there is being produced too much of all those necessaries of life which come from the farms is based on the most obvious contradiction of all agricultural history. In the long run it must be by improved methods of production and by the further elimination of the wastage and destruction due to crop diseases and crop pests that it will be possible to increase the returns of the farmer, without the danger of limiting his market by increasing costs to the consumer. References to the tremendous response of farmers to the demand for increased production that came with war conditions too frequently include no reference to the question of costs.

Pathology is, it is now frequently said, nothing but abnormal physiology. Virchow's dictum that all disease is disease of cells is a commonplace of accepted theory today, and the history of the cytological study of plant pathology, with its every step marked by the discovery of new types of specific interrelations between host cells and parasites, has verified Virchow's conception in its every aspect. It was by cytological methods that the old misconception that the pathogen is the product of the diseased host cells was finally eliminated. There are those today who are justly much distressed because modern pathology, especially plant pathology, tends to be so wholly limited to a consideration of the life history of the pathogen that the functional disorders of the host are quite neglected, but in both fields progress has been made in direct proportion to increased knowledge of the intercellular relations of host and parasite at each stage in the life history of both.

On the firm foundation of this knowledge of cellular inter-relations, there is now beginning the further study of the effects of environmental changes, such as temperature, soil, acidity, moisture, etc., on this cellular host parasite complex, and I think it is safe to predict that only as this analysis of environmental factors extends to the recognition of definite and specific cell effects will its contribution be of fundamental significance for the understanding and control of plant disease.

The microscope and cytological methods bid fair just now to reveal some of the secrets of the baffling problems of "mosaic" and related diseases though there is also evidence that its revelations may mislead the unwary as well as enlighten the judicious. Will the solution of the mosaic problem clear up the whole train of functional degenerations of the potato, even to curly dwarf and spindling tuber, as well as the long series of infectious chloroses in other crop plants? It is clear enough now that anyone with the requisite patience and technical skill could, in Beijerinck's time, have seen the bodies in mosaic cells which many now are finding. Whatever these bodies may prove to be, they constitute a definite new element in the problem and in the broader view it is no mean achievement to have brought such diverse diseases as tobacco and corn mosaic and wheat rosette into a suggestive relation with certain animal exanthemata, with their associated chlamydozoa, whatever these puzzling structures in turn may prove really to be.

With all the uncertainties that lurk in these most difficult and obscure plant pathological problems, the cytologist may, it seems to me, feel sure as a working hypothesis that ultimate solutions will be reached only with the discovery of the cell disorders which lie back of symptoms, as shown in leaves, stems, tubers, etc., and in the light of past experience it seems to me the further working hypothesis is justified that these cell disorders, whether due to pathogenic organisms or to autolytic functional disbturbance, will be most clearly characterized and interpreted by means of a clear understanding of the changes which they induce in the visible organization of the cell.

It is in the study of the series of grades and types of cellular interrelation between host and pathogen that cytology has contributed and apparently is destined still further to contribute to the fundamental concepts of pathologic theory. Apparently, it will soon be possible to clear up and quite reverse some of the most fatal and misleading concepts as to the interactions of host and pathogen which have dominated the theories of animal pathologists. It has been found that in highly specialized parasites, including those most dangerous to the great cereal crop-plants, the old dictum that predisposition to attack is a matter of lowered vitality and resistance is quite the opposite of the truth. In some cases a condition of vigorous health is even a prerequisite to infection by the parasite. Further, in many cases the parasite, far from giving off toxic compounds to kill and rot the tissues of the host, punctures its cells with delicate haustoria which serve merely to withdraw food materials with a minimum of immediate damage to the invaded plant, though in the

end resulting in its starvation. It is only in the case of the lower unspecialized and saprophytic types that, as should be expected for saprophytes, the weakening or wounding of the host favors the entrance of the parasite. In such cases, not having developed high mutualistic specificity in its relations to its host, the parasite acts only by enzymatically softening and corroding its tissues and thus ultimately destroying them. Parasitic fungi in their cell relations with their plant hosts are found to form a series from the least specialized semi-saprophytes to the most highly specific obligate parasites. There is evidence that a similar situation is more or less common among animal pathogens. It is obvious that carefully controlled and intensive cultural methods leading to the utmost vigor of the crop plant may favor its escape from disease in the one case while such treatment will be entirely without effect or may favor the pathogen in the other. It is the field of cytology in its relations to plant diseases to discover the fundamental facts as to the varying cellular relations between host and parasite as a basis for the most rational procedure in the development of protective measures.

The major crop-plants may be thrown into the commonly accepted grouping of those grown for forage and those grown for their seeds and fruits. It is obvious that the second group far outweighs the first in the specificity of its significance to mankind however it may be with tonnage in the production of butcher stock. It is the great outstanding fact for the agriculturist that the basic staples of human dietaries are the seeds of the cereals; including, of course, rice, the millets, etc. This being the case, it is equally obvious that in the last analysis it is the sexually reproductive seed-producing function of the plant which is of most importance in all schemes of agricultural practise. That this fact is only vaguely realized in much experimentation will, I think, be generally agreed. In fact, investigators are only now beginning to distinguish between growth and reproduction in experimental methods and to endeavor to test directly their complicated interrelations. Of course, it has long been known and endeavors have been made to provide in fertilizers for such obvious differences as those between grain and straw when chemically analyzed, and search is now being made for the limiting factors, whether involving feeding or heredity, nurture or nature, which determine maximum grain production with minimum necessary straw production. This is, of course, the very essence of the farmer's problem. It is, in the last analysis, a problem in the interrelations of the processes of asexual multiplication of cells by division and sexual reproduction by cell fusion.

With the problem thus presented in its essential elements one is confronted with a curious situation as to the relation of the various divisions of plant science in their attack upon it. Seed production is certainly a physiological function of the plant, but in the literature of plant physiology there are only the most casual references to it. If the functions of plants be classified from the standpoint of the activities of their cells there may be recognized roughly three groups: 1. functions of nutrition and growth or metabolism; 2. functions of response to environmental stimuli or irritability; 3. functions of reproduction both sexual and asexual. The standard manuals of plant physiology treat almost exclusively of metabolism and plant response to the entire, or almost entire, exclusion of reproduction.

Pfeffer's great manual, by the limitation specified in its title, treats only of metabolism and of the energy relations of plants in growth, with little or no reference to reproduction. Dr. Barnes remarks that, since reproduction is treated so fully under the head of morphology, it is unnecessary to discuss it further under the head of physiology. Bayliss, in his great treatise on what he calls general physiology, deals almost wholly with the physiology of metabolism, nutrition and respiration, excitation and inhibition, secretion, etc., and with the special physiology of the nervous system, muscular system, circulating system, etc. Reproduction is given a little over one page and heredity two or a little more of the 816 pages in the book. The page on reproduction is partly given to regrets that the "sexual process should have become the subject of unseemly jesting."

Turning to the cytological manuals we find them quite as exclusively devoted to the functions of cellular reproduction, both sexual and asexual, and not pretending to cover the field of cellular activities in all their aspects. An exception is to be noted in the new book by Meyer, entitled "The Physical Analysis of the Cell." This work, in the volume issued, limits itself just as predominantly to the phenomena of cellular metabolism. It is to be hoped that this is the forerunner of books which may aim to present, in well balanced form, the whole field of cellular organic functions; in which neither metabolism nor reproduction shall be treated as representing the whole or the dominating phase of life phenomena.

The explanation of this division of the field between the so-called cytologists and the so-called physiologists is, of course, very simple. The physiology of the manuals uses almost exclusively the methods of chemistry and physics. The processes of reproduction have been almost wholly worked out by the methods of cytology. The physiology of reproduction stands first as the field of work of the cytologist,

and it is here that the great cytological contributions have so far been made and are being made.

The problems of the plant breeder fall into two simple groups: first, to produce new improved varieties with any desired combination of qualities; and, second, to be able to maintain these new types and propagate them on an unlimited commercial basis. In both these lines, as is true in so many fields of human activity, practice long antedated theory and, we may say, was perfected in spite of all sorts of false theory, as witness Nehemiah Grews fantastic explanation of the nature of grafting. That a rich harvest has been won by cytological methods in the whole field of plant breeding and propagation is obvious. With the discovery of the paired birth of the daughter chromosomes with each new cell division, the possibilities and the limitations of all the various methods for the vegetative propagation of fruit trees, small fruits and berries, are established on the firm foundation of an understanding of the very nature and meaning of the complex cellular processes on which they depend. A flood of light was thrown on the underlying cell functions which are the basis of the established methods of the horticulturists by the discovery by Strasburger and his colleagues and followers of the chromosomal complex with its marvellous fixity of number, size, form and even spatial interrelations in the plant cell. These discoveries, at a stroke, made clear the functional basis of those age-old practises of vegetative propagation in use by all gardeners and horticulturists and on which practically all commercial fruit production is based.

However, the subject still presents many problems. In recent practise bud variations are being made more and more the material for selection in the effort both to improve and standardize established types. Does repeated bud selection in the case of vegetatively propagated stock tend to reduce variability? Can bud selection be made the basis for obtaining permanently improved types? Is there such a thing as clonal degeneration independent of the intervention of a pathogen or climatic inadequacy? With the greater refinement of modern horticultural methods and the demand for a genuine standardization of types in commercial fruit production, the solution of these problems becomes more and more pressing.

That the study of the processes of cell division should reveal a mechanism so perfectly adapted to maintain at least a high degree of constancy of type through generation after generation of vegetatively propagated individuals is the best of evidence that cytological methods are adapted to and reliable for the investigation of the fundamental functions of the plant. The mechanism for the main-

tenance of constancy of type has been discovered. Will the same methods make possible the solution of the perplexing problems of variation and deterioration? The cytological study of sexual reproduction has led to the discovery that seed production is initiated by a complex process of cell fusion extending to and ultimately involving the mating of the homologous pairs of chromosomes as found in the diploid cell. The cellular processes which lie back of the breeders long-practised art of crossing and selecting are thus made clear.

The details of the processes through which the germ plasm passes in sexual reproduction have been most laboriously worked out and the behaviour of the chromosomes in the reduction division has been shown to be a matter of very great complexity. Their history is initiated by the appearance of the paired chromatic spirems. Then follows the contraction into the synaptic knot, the formation of the thick pachyneme spirem, second synapsis and the final emergence of the tetrad chromosomes ready for the chance distribution of their units to the germ cells. Granting that there is uncertainty as to the facts at many points, still the whole constitutes a body of cytological data of the first magnitude not only in their relation to the phenomena of reproduction and heredity but in their bearing on the fundamental nature of all life processes.

DeVries, in 1903, pointed out the correspondence between these phenomena, laboriously worked out by microscopic methods, and the familiar observations of the plant breeder in hybridizing for the production of new varieties. It was this striking parallelism between the behaviour of the germ plasm in chromosome reduction, fertilization, pairing, and the diploid condition of the sporophyte, and the long-known facts of constancy in first generation hybrids with breaking up in the second generation, or (as it is now expressed) segregation and recombination of factors in the so-called Mendelian ratios, which initiated and has continued to stimulate the great interest in the experimental study of heredity which has characterized the last two decades.

I shall not go further into this problem of the cellular basis of heredity and variation. So much has been achieved, so much is in question, and so much has been promised, that it must remain for the future to show whether the discovery of Mendelian conceptions and their further modifications has provided as clear and cogent explanations of current practises in the breeding of new and improved types through sexual reproduction as the older cytological study has given of the basis of horticultural practise in the maintenance and propagation of new and improved forms when once they have been

produced. Advance has been so rapid that cytologists and geneticists alike may plead extenuating circumstances if there appears some evidence of intoxication with the wonder of these discoveries.

I wish next to speak of the great importance of further and fundamental studies in microchemistry—the application of quantitative chemical methods to the problems of the individual cell metabolism.

It is to be noted at once that relatively little progress has been made in these lines in recent years. The newer manuals, like those of Tunmann and Molisch have little to add to what was to be found in their predecessors. It is becoming increasingly evident that new and more refined methods of microchemical analysis must be found in order to study successfully the processes of assimilation and excretion, food use and food storage, from the standpoint of the cell cycle. No one will question the great practical significance of problems whose solution may ultimately give us more exact data in terms of standard units of the cost of production of our great agricultural staples.

In urging the importance of a more exact knowledge of the kind and amount of materials used and products formed in terms of cell constituents, I am proposing no new problem. The fertilizer tests, the variety tests, the rotation tests, and the soil analyses made at the agricultural experiment stations have all had in view the aim of standardizing the methods of crop production. Very important results have been achieved and much useful advice is now available to the farmer as to how to feed his crops and how to select the most productive varieties. But in spite of all the progress that has been made in developing a so-called rational system of agriculture we are still far from being able to compare different staple crops or different methods of crop production in terms of unit requirements of raw materials, work done, and finished products.

Exact quantitative data as to the rate of carbohydrate formation, under specified conditions of illumination and CO_2 supply in the much-studied process of photosynthesis, are still lacking. Neither the older work of Sachs nor the later studies of Browne and Escombe have yielded results which can be made the basis of practical applications. The recent extensive studies on the salt requirements of crop-plants have yielded no decisive quantitative data. There is still disagreement as to the rate of increase in growth and total production which will result from increasing by successive definite increments any nutrient, even when this is, in the ordinary sense, the sole environmental limiting factor. There are, of course, those who discredit the possibility of ever standardizing processes in which the behavior of a living or-

ganism is involved. It seems to me, however, that in this connection cytology has a contribution to make, both as to the theoretical possibilities and as to the practically available lines of advance on the problems involved. As to the theoretical possibility of obtaining such data, it seems to me there is general unanimity among students of the cell that however widely we may diverge in our opinions as to the ultimate constitution of protoplasm there is practically unanimous agreement that the cell is a mechanism.

The rate of growth, the food requirements, the temperature relations, etc., of the growing cell are all to be measured in terms of the ordinary physical forces and chemical transformations as they appear in unorganized materials. The doctrine of the existence of a so-called vital force has been finally disproved. The so-called "neovitalists" are all careful to affirm that the existence and operation of the controlling principles which they invoke are in no way incompatible with the principle of the energy balance in the total income, outgo and work done of a living organism. In the light of the available data it is possible to discriminate between the ultimate problems as to the nature and constitution of the cell mechanism and the problems as to the rate and efficiency of its operation.

Since Virchow's time, scientists have recognized, theoretically, the facts but no one has practically applied the conceptions of the cell theory in studies of plant feeding and growth. The units of production in all the life and growth processes of the plant are the individual cells. In studies of crop production investigators, for the most part, have been regarding the plant, such as the wheat plant, the potato plant, the apple tree, etc., as the unit of growth and fruit or seed production, with too little attempt to distinguish the varying requirements of each operating cell unit, its special location and the particular service required of it in the plant as a whole.

The plant is a complex of feeding, growing, and finally self-reproducing units, the cells each working under a particular set of local conditions which limit in specific fashions the attainment of its greatest effectiveness. The growth rate and production of the entire plant gives only a generalized and uncritical picture of the real conditions of effectiveness for the cells themselves. The requirements of each tissue or organ constitute limiting factors for the organism as a whole and the requirements of the individual cells as such constitute limiting factors for the tissue or organ in which they are. This fact is coming to recognition in the attempts which are now being made to study independently the growth rate, chemical constituents, environmental requirements, etc., of special parts of the plant, such as

the fruit spurs in an apple or pear tree, or the temperature requirements of roots as contrasted with leaves, etc.

The importance of such studies as bearing on cultural practises in crop production cannot be overestimated. But it is obvious that such approximations to the study of the cells themselves can only have a relatively greater significance than similar studies on the entire plant. What is required, it seems to me, is, as I have noted, a quantitative study of the cell metabolism itself.

In a word the difficulties which limit advance lie in the minuteness of the unit amounts of the indefinitely numerous chemical compounds whose transformations in the aggregate express themselves in the visible processes of growth and fruit production. The mechanism whose efficiency should be standardized lies in the realm of the microscopically minute. Such suggestions as this may seem wholly impractical and to belong to the domain of fancy rather than that of careful, feasible, scientific research. But in the formulation of problems the real desirability and value of the solution sought is a thing to be considered, as well as the likelihood of its immediate attainability. The fact that progress in these lines of micro-chemical research has been slow is to be set over against the fact that all fundamental research on the processes of nutrition and growth seem to lead back inevitably to problems in one or another of the aspects of microchemistry. The food salts in soil moisture are apparently in extreme dilutions. The percentage of such essential and significant elements as phosphorus and sulphur in the total weight of a tissue is very low. The kelp is able to accumulate in its protoplasm appreciable amounts of iodine from the almost chemically unrecognizably minute amounts of iodine in sea water. Unquestionably, the greatest recent advances in the study of cell metabolism have been made first in the discovery of enzymes with their specific relations to a vast variety of cell processes; and, later, the discovery of the so-called hormones and vitamines. All of these are substances which are active in dilutions so extreme as seemingly almost to defy the possibility of chemical recognition. The amounts of these substances necessary to affect vitally the activities of a single cell are minute beyond the powers of chemical description. Yet it is in this order of magnitudes that the essential life processes are expressed. These problems require not merely the qualitative and quantitative recognition of the elements as such, but the ability to discriminate chemically the numerous proteins, the sugars and pentosans, the simple fats and the lipoids.

That the possibility of identifying the elements as such in the minute amounts in which they are present in a single cell, regardless

of their specific combinations in any given case, would be of vast significance is, however, shown by the interest awakened some years ago by the claim of the discovery of a method for the microchemical recognition of potassium, iron, phosphorus, and chlorine in the cell. Many suggestive observations and bold hypotheses as to the nature of the permeability factors for the cell wall and plasma membrane are awaiting for their confirmation the discovery of a method for the determination of the amount and distribution of calcium in the protoplast and the cell boundaries. Yet it seems to me to be true that the hopelessness of any advance on the problems of metabolism along microchemical lines is so great that not only little attempt is made in this direction but workers are so obsessed with the methods and viewpoints of macrochemistry that microchemical data remain in some cases unregarded. This is true, it seems to me, in the study of photosynthesis. The methods of attack on this problem have become almost formally stereotyped in the line of the chemical study of the breaking up, reuniting and polymerizing of carbon dioxide and water under the sensitizing influence of chlorophyll. As a result, the microscopic evidence that in a great series of plants which have pyrenoids the starch grain begins as a segment of this presumably protein material is wholly overlooked.

In this connection it is interesting to note that Brunswick in a very recent paper on the "Limitations of Microchemical Methods in Biology" (Die Naturwiss., Nov. 2, 1923) reaches the conclusion that the ordinary methods of chemical procedure by precipitation in crystalline form of the substance sought are not sufficiently sensitive to permit the detection of the amounts of the common kations, much less of the amino-acids, proteins, etc., which are found in the single cell. He concludes that (considering a very favorable case) KCl would have to reach a concentration of 0.2% in order to be detectable in the cell protoplasm. In the majority of cases, the cell sap would have to be a 20% to 50% solution of the salt in question in order to give a positive result. This is, of course, as Brunswick notes, merely reducing to mathematical forms of expression the ordinary experience of all those who have attempted to study directly the quantitative make-up of protoplasm as found in the living cell. What is needed are methods of analysis sufficiently sensitive to enable one to attack the problems presented by substances in amounts of this order of magnitude. Brunswick admits that what he calls the physical methods of staining, etc., are not subject to the limitations of the precipitation methods and it is with the staining methods that the advances in knowledge of cellular reproductive methods have been made.

The feeling expressed by Brunswick that further progress along the lines of the microchemical study of the cell is practically impossible is, I fear, widerspread and yet it seems to me equally clear (as I have already emphasized) that there is no field in the whole realm of the biological sciences regarding whose fundamental importance there is such general agreement. There is no other field in which new facts and new methods would be more significant and more illuminating as to the truth or falsity of the conclusions which are reached in all other lines of physiological, pathological, and genetical research. What would it not mean in fertilizer practise if it were possible to see and differentiate in the egg and male cell the exact kind and amount of chemical compounds which accompany reproduction as contrasted with vegetative growth! It would be vastly illuminating if one could with certainty recognize the amounts and kinds of the amino-acids at each stage in cell growth as they combine to form the cell proteins, or if one could even trace visibly the series of transition compounds which accompany fat assimilation or fat storage as found in the plant cell. One can hardly conceive anything more important than the possibility of recognizing in the cells themselves microchemically the presence and distribution of catalyzing, regulating, and mobilizing substances. The whole study of plant nutrition would be placed on a firmer foundation if it were possible to follow visibly in the cell the appearance, distribution, relative amounts, etc., of the materials which by macrochemical methods of analysis have come to be considered essential for the processes of growth and fruit production.

To turn to another field, geneticists are specially in need of methods which would enable them to test directly the chemical similarities and dissimilarities of different chromosomes and much more the evidence for the presence of different chemical compounds arranged in serial order in the same chromosome. In general, one can hardly imagine any field of experimental biological science which would not gain immensely by advances in the field of microchemical methods of analysis.

I will conclude by noting a comparison which may seem quite as unconvincing as my attempt to state the intangible and almost fanciful problems of the microchemistry of the cell. The situation is with students of the chemistry of the cell *mutatis mutandis* as it was with the astronomers before the development of spectroscopic methods for the identification and further study of the chemical constituents of the stars. The factors of cosmic evolution, of star growth and decadence, were as much beyond the realm of study of the chemists be-

cause of their immensity as are the phenomena of cell growth, maturity, and decadence because of their minuteness. The vast new fields of observation and interpretation which have been opened up with the utilization of spectroscopic methods in astronomy suggest the possibilities which would emerge with the discovery of relatively equally effective methods for the chemical study of the microscopically minute.

5. BIOCHEMISTRY[1]

Ross Aiken Gortner[2]

Agriculture is the basic industry of the world. All of the activities of mankind can, in the last analysis, be translated into the bushels of grain and pounds of meat which are necessary to supply his energy. More than one hundred years ago, Malthus in his "Essay on the Principle of Population" stated that, "The power of (increase in) population is indefinitely greater than the power of the earth to produce subsistence for man." Pearl (1)[3] has recently had occasion to re-examine the problem which troubled Malthus and states, "It will appear with startling emphasis that nothing which has happened since 1798 has in the least degree mitigated or softened or altered in any true sense the relentless insistence of Malthus's logic. On the contrary, the developments of the last century have made it far plainer even than it was to so clear visioned a major prophet as he was, that the population of the world cannot go on increasing at anything like the rate of growth that has prevailed in the past more than a short time longer." East (2) points out that the normal increase in population of the world calls for an additional thirty-seven million acres each year to be brought under the plow. Much of the desirable agricultural land is already under cultivation; in the near future more and more of the undesirable land must be utilized if the world does not go hungry. As a biological friend of mine recently remarked, "If our grandchildren do not face this problem, their grandchildren certainly will."

Taking, therefore, the thesis that agriculture is the basic industry of the world because it produces the food of man, and adding to this the thought that, within at the most a few short centuries, the food

[1]Paper read as a part of the symposium on "Research Fundamental to the Solving of Crop-plant Problems," at the meeting of the Society held in Cincinnati, December 28, 1923.

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[3]Reference by number is to "Literature Cited," p. 614.

available will limit population, it is wise to take stock of the present supply of knowledge and to endeavor to find new tools which may be enlisted in the service of agriculture. It is my firm conviction that one of the most potent tools lies in the application of our knowledge of biochemistry to problems of agriculture.

Agricultural chemistry in America is largely the outgrowth of the development of our agricultural colleges and experiment stations. In many instances, the work in agricultural chemistry has been sharply delineated from that in so-called "pure" chemistry, in that the agricultural chemist is supposed to attack only economic problems which appear capable of solution. No doubt, this requirement has prevented in many instances a solution of the problem, for the theoretical basis which must precede the practical application was unknown or imperfectly understood.

On the other hand, the so-called "pure" chemist may be even more incapable of applying his theoretical knowledge to agricultural problems, for, while he knows the theory he may not recognize or understand the problems which arise in actual practice, or he may not recognize the barriers which limit the application of laboratory knowledge to agricultural practice. The agricultural chemist should be more than a chemist; he should have a rather broad knowledge of the fields of animal biology and botany, a rather detailed knowledge of cell structure and function, and above all an absorbing interest in every phenomenon which is or may be involved in living processes, for in the last analysis agricultural chemistry is more truly biological chemistry than is the pathological chemistry which is often misnamed "biological chemistry" in the curricula of our medical schools.[4]

We live in an age of wonders, an age in which miracles happen every day and yet produce no comment! Even the younger men among us have seen more startling discoveries within their short lifetime than were revealed to generations of their forebears. The automobile, wireless telegraphy, the aeroplane, radio, radium, and the transmutation of the elements are only outstanding landmarks in the general progress of science. The scientist is no longer pictured in the popular imagination as a sorcerer in league with the powers of evil. Less than two centuries ago the first chemical laboratory in America, at Yale, was a secret basement room, entered through a trap door in the floor so that it might not be publically known that the "Black Art" was being practiced. Today in the popular imagina-

[4]The above paragraphs are essentially identical with the opening paragraphs of an address by the author on "The Application of Colloid Chemistry to Some Agricultural Problems" delivered before the Colloid Symposium at Madison, Wisconsin, June, 1923.

tion *and in reality* the scientist is slowly rolling back the curtain of ignorance and superstition and is placing in the hands of mankind powers beyond the wildest dreams of the imagination of a generation ago.

And just as there has been an alteration in the attitude of the public toward the scientist, so has there come about an alteration in the attitude of the scientists toward each other. They have come to realize that the scientific paths, which a few years ago seemed so far apart actually have come close together and at last have merged into a great highway of cooperation and progress. No science is sufficient unto itself. This is particularly true of those sciences which are concerned with life and living processes. All of the available information of all of the sciences is still far too little to solve many of the problems of life which appear capable of solution. The first and greatest need in agricultural colleges and in experiment stations, if we are to progress as we should progress, and if we are to do our part in the present economic crisis, is to permeate our research staffs and our extension forces with the spirit of *cooperation*. Just so long as a single research worker reserves for his own selfish purposes information or assistance which may aid a brother scientist in a solution of his problem, just so long will we fall short of the ideal which we should attain. It is for this reason that I say that the agricultural chemist must be more than a chemist, that he should have a rather broad knowledge of the fields of animal biology and botany and above all an absorbing interest in every phenomenon which is or may be involved in living processes, for he must cooperate with the biologist, he must see agricultural problems in their economic as well as in their scientific aspects, and he must realize that just as a group of isolated cells do not make a complete organism, neither do a few isolated research workers make a real Agricultural Experiment Station.

I may perhaps be criticized when I say that agricultural science depends in the last analysis on the principles of physics, chemistry, and mathematics, but I firmly believe that when the last chapter is written in biology, it will be written in terms of physics and chemistry as expressed in mathematical formulae. This does not mean that the botanist, zoologist, geneticist, physiologist, and pathologist will be relegated to the limbo of the obsolete, but rather that as they progress in their respective fields, they must cooperate more and more with the physicist and chemist in the study of their materials.

I have been asked to consider some of the outstanding problems which the chemist may assist in solving and which must be solved in the near future, if the agricultural program is to go forward.

In the first place there are the vast areas of arid and semi-arid land which either lie idle or else furnish only a scanty range for animal production. Nature has endowed certain types of plants with a mechanism which permits them to persist under conditions of extreme drouth and to grow rapidly when the scanty rainfall comes. A study of the mechanism possessed by these plants may yield a clew to a laboratory test for drouth resistence, so that the present economic waste of the time of the plant breeder and agronomist may be greatly curtailed. At present, a great number of hybrid plants are grown in varied localities in order to determine which ones are adapted to that particular region. Out of thousands of individual plants and years of patient labor, only a few selected strains, at the most, survive and are recommended for propagation. If one could eliminate, by a laboratory test, the thousands of plants which must fail, there would be saved large sums of money and much effort which could be expended in enlarging our agricultural program. Such a project may appear visionary, but its possibility is evidenced by the fact that a laboratory test has been recently devised for winter hardiness in wheats (3 and 4). There is now available a method for comparing the relative winter hardiness of a series of wheats under identical conditions and of testing hybrid wheats without resorting to long and expensive field trials. If it is possible to eliminate only ninety per cent of those hybrids which are *non*-hardy, there can be concentrated on the remaining probably hardy hybrids all of the research workers' time and energy and all, of the usually too few, field plots of the experiment station. Such laboratory tests would likewise make possible the breeding and testing of plants for winter hardiness and drouth resistance at experiment stations located in regions where the climatic factors did not favor elimination of the unfit in field tests.

Another problem of the arid and semi-arid regions concerns animal production. Over a very considerable protion of this area, the water is alkaline, saline or brackish. Certain evidence appears to indicate that the salts present in such waters interfere in a marked degree with normal metabolism, growth and reproduction. It is a rather remarkable fact that while the "antagonism of ions" has been studied from the standpoint of water cultures of plants and for developing sea urchin and star fish eggs, practically nothing is known about "antagonism of ions" as a possible influence in animal production. A study of this field is already projected at one experiment station and should yield valuable information from the purely scientific, as well as the practical, standpoint.

The production of new and better insecticides and fungicides will

assist in increasing the yields of farm products per unit of area and of labor. Some notable advances have been recently made in this field where the newer theories of colloid chemistry have been applied. It has been shown (5) that a positively charged collodial particle will adhere to a leaf surface (negatively charged) with great tenacity and that if a positively charged arsenical is used to spray the young leaves, there will still be sufficient arsenic on the leaves which are ready to fall from the tree at the end of the season to kill leaf-eating insects (6). The same principle has also been applied to fungicides with essentially identical results (7).

It is preparations of this type that may serve for the protecting of forests from the various plant pests. It may be possible to control epidemics over large areas by the use of an aeroplane and properly prepared insecticides, insecticides which will adhere so tenaciously that a single light application will protect throughout the entire growing season. It is a rather interesting fact that the scientist not fully conversant with all aspects of the problem may be wrong in his reasoning. The statement has often been made by farmers that the arsenicals of recent manufacture are not as effective as were the preparations of fifteen and twenty years ago. The chemist has proudly pointed out that the farmer was wrong, that the insecticides are purer and contain *more arsenic* than ever before, and consequently must be better. As a matter of fact, the farmer was probably right, for pure lead arsenate has a negative charge and easily washes from the leaf whereas a basic lead arsenate, containing less arsenic, carries a positive charge and adheres much better.

The field of cereal chemistry and bread manufacture offers problems at every hand. Many farming areas produce wheats which do not possess the most desirable bread-making qualities. There is urgent need of standards for wheat and flour quality which will replace the more or less rule-of-thumb methods which are now used in cereal and bake-shop laboratories.

The low yields in the spring wheat areas, together with the increased cost of labor and farm machinery, present a serious economic problem at the present time. Sooner or later the relatively low yielding hard spring wheats must be more or less completely replaced with the higher yielding but softer winter wheats. The problems of producing desirable bread from the softer wheats is a problem to be solved by the cereal chemist, working in cooperation with the managers of the large bake shops. The utilization of the durum wheats, particularly adapted to dryer areas, is also a problem which should receive careful consideration in chemical laboratories.

The role of the biochemist in the field of nutrition is so evident as to need only passing mention. Much has been accomplished within recent years, but much more remains to be done. The health of the nation and the future of the race are intimately associated with the projects of nutrition laboratories.

As the day approaches when the food supply which the world can produce is the limiting factor in growth of population, human beings will more and more depend upon the vegetable kingdom as the source of energy and of protein for maintenance and growth. Present methods, while satisfactory from the dietary standpoint, are extremely uneconomical from the standpoint of the problem of feeding a hungry world. Trowbridge (8) has pointed out that an average acre will produce about 1960 pounds of corn and that if this corn is fed to swine it will produce 289 pounds of pork fit for human consumption and this 289 pounds of meat will contain 19.9 pounds of protein and 116 pounds of fat. In feeding the corn to hogs, there has been a loss of 184 pounds, or more than 90 percent, of the protein, a loss of 1360 pounds of carbohydrates, and a gain of only 18 pounds of fat in converting the corn into pork. Only 16.2 per cent of the digestible nutrients of the corn has been returned as human food! This figure is practically the same when the calculations are made for beef cattle feeding. Eventually, the grains must be utilized by man, and the meat supply be derived either from animals which are able to convert roughages not utilizable by man, such as hay, straw or corn stover, into human food, or else from the sea and inland lakes and streams. An intelligent policy of fish preservation and propagation, laws regulating stream polution and a survey of marine resources should be undertaken in the immediate future. The agronomist and the chemist must work together in the development of crops capable of being directly utilized as food for man. The vegetable proteins must be studied to determine whether or not they are adequate for maintenance, growth and reproduction, and the public must be intelligently educated in the essential principles of nutrition.

The agricultural chemist, with his intimate knowledge of the process operating in living tissues, may assist in the solution of many problems vexing the industries. The following rather striking illustration of such cooperation was recently brought to my attention. A company manufacturing sorghum syrup had experienced great difficulty in the filtration of the juice after defecation. Large filter presses had been installed and tons of diatomaceous earths were used yearly to hasten filtration, but the rate of filtration was still the determining factor in controlling production. The collodial constit-

uents of the juice which prevent rapid filtration were broken down by a suitable enzyme preparation suggested by the agricultural chemist. Filtration was enormously speeded up, only half the number of filter presses was required for a given volume of juice and the decreased consumption of diatomaceous earth not only paid for the extra expense of the enzyme treatment but produced a net saving in excess of $2,000 per season.

Of a host of other projects which might be mentioned, only one will be chosen, namely, the utilization of the waste products of forests and wood-using industries, for the forests are one of the most important agricultural crops. America has been called the land of opportunity. It might equally well be called the land of appalling waste. Americans have been reckless with the heritage which nature provided, have believed that the country's resources were inexhaustible; but the day of disillusionment is already at hand, and the country is face to face with the problem of a future timber supply. Many of the great timber-exporting states of twenty years ago are now importing more wood than they produce, and yet only 40 to 50 percent of the timber which is cut yearly is actually utilized by man. The remainder is wasted, either burned, or what is still worse, left as slashings upon the ground to increase the fire menace of our forest areas. All of this waste wood contains valuable chemical products. Research is necessary in order to provide for their economic production, and such research is just as much a function of the agricultural experiment stations as are problems concerned with the sugar beet or the cereal grains. An old cartoon of Napoleon shows the Prince of Rome being given a sugar beet with the caption, "Suck baby suck! Your daddy says it's sweet!" The agricultural chemist and plant breeder have made the sugar beet an agricultural asset. Why should not the chemist succeed again in the economic utilization of our industrial wastes?

The World War bequeathed to the nation an enormous debt, the cost of living has increased by leaps and bounds, taxation has increased from year to year. The only way by which it will be possible to pay national, state, and municipal debts is to improve methods or to curtail waste and turn it to profit. This applies to land areas, to forests, to mines, to factories, and to farms. This is, and for many generations will be, an agricultural nation, and so long as it is an agricultural nation there will be need for agricultural experiment stations to ascertain new truths and better methods in the application of scientific principles to agriculture.

I will close as I began with a plea for the sympathetic cooperation

of all scientists in the problems which are before us. We have only begun to realize that the problems of the botanist, the zoologist, and the chemist are in many instances only different phases of a larger whole, and that the entire research program may be greatly stimulated by the help which our research workers can give each other. Research progresses under the spirit of cooperation not in an arithmetical series but in at least a geometrical ratio.

LITERATURE CITED

1. PEARL, R. The population problem. *In* Geog. Rev. 12: 636–645. 1922.
2. EAST, E. M. Future food problems. *In* World Agric. 2: 130–132. 1921.
3. NEWTON, R. A comparative study of winter wheat varieties with special reference to winter killing. *In* Jour. Agr. Sci. 12: 1–19. 1922.
4. ——— The nature and practical measurement of cold resistance in winter wheat. Thesis, University of Minnesota. 1923.
5. MOORE, WM. Spreading and adherence of arsenical sprays. Minn. Agr. Exp. Sta. Tech. Bul. 8. 1921.
6. Private communication from Dr. Wm. Moore.
7. HOOKER, H. D. JR. Colloidal copper hydroxide as a fungicide. *In* Jour. Ind. Eng. Chem. 15:1177–1178. 1923.
8. TROWBRIDGE, P. T. The meat problem. *In* Jour. Off. Agr. Chemists. 4: 311–320. 1920.

6. GENETICS[1]

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The purpose of the research conducted by the various agricultural experiment stations is, or ought to be, primarily concerned with the production, utilization, or conservation of the food supply. That the field of genetics may have a share in this purpose and does have a contribution to make will, I think, be admitted by all. The research work in plant genetics has made some very definite additions to the solving of problems of production. These are in addition to the many valuable new varieties produced by plant breeding as the result of selection or hybridization.

In this paper, it will not be possible to give a complete review of the fundamental genetic research which may have an effect on solving crop problems. Any omissions are due to lack of time rather than any intentional omission and the author trusts that this will be understood. Also, it is possible that in a short survey of this subject

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certain crop-plants may be emphasized more than others. This is partly influenced by the field of work in which the writer finds himself engaged.

Before considering any special types of problems, it will be well to consider first the general subject of genetic research. It is important to agree that any well planned and thoroly prosecuted piece of research on economic plants may establish some very fundamental facts. Such facts may be of utmost importance in helping solve some problem connected with food production. Since this is so, it is important that all such researches be given encouragement and that they be continued and enlarged in the various institutions.

In this connection, it may be stated that investigations as to the inheritance of various characters of plants and a study of their interrelations and linkages may and do furnish some very valuable aids to the solving of more practical problems. No one, *a priori*, can say that the results of an investigation will not have any influence on agricultural practice. What I wish to emphasize is that certain fundamental researches in plant genetics may have a very profound effect on the food production of the country, even tho at the outset the practical application may not be considered. At the same time it is well that those who work in plant genetics in the agricultural experiment stations do not go too far afield in the planning of their projects. I do not mean by this statement that the workers should be limited to the more practical problems, but that so long as so much needs yet to be done with the economic crops that the research work be conducted with these crops if the problem under investigation can be solved by their use. There may be times when a principle can be worked out to better advantage and more economically by the use of some rapid-growing, short-lived, non-economic plant. It must be agreed that research work is no less research if it leads to some practical result than if it does not. It is also well to consider whether it is proper to use public funds to conduct research purely for the sake of research.

Research work in the field of plant genetics has aided practice in two ways. One is by giving some immediate contribution and the other is that by conducting some fundamental investigation the way has been opened for the solving of some problem of real practical importance.

One of the very important results that has been the outcome of research in the general field of genetics has been the contribution of methods that may be used in plant improvement. For example, some of the early studies on the breeding of corn were disappointing in that progress toward the end in view was not so rapid as had been

hoped. In fact, in some cases where selection was directed toward increased yield, the result was that no gain was made. This led to investigations which brought out the fact that corn suffers greatly by too much inbreeding. This caused a change in the method of corn breeding so that in similar experiments steps are now taken to prevent too close inbreeding.

An experiment that was planned to study the possibility of changing a character by continued selection within a pure line has had a profound effect on the methods used in plant selection. Johannsen (1)[3] was the first to conduct a carefully planned experiment to determine whether a character could be modified by selecting for several generations within the offspring of a self-fertilizing homozygous race. Johannsen applied the term "pure line" to the plants that were the offspring of such a race. The material used by Johannsen was beans. He proved conclusively that when one had a pure line the type cannot be changed by selecting different types within the line.

This idea has now been extended to other crops and a number of experiments along similar lines have been conducted. An experiment with oats conducted by the author will be mentioned here. Selection work was begun with oats to determine whether it was possible to change the stature or height by selecting within a pure line. A crop of oats was grown and a large number of the plants measured. Seed from some of the tall and some of the short plants were selected to grow the following year. From this time on, tall plants were selected each year from those lines that had been grown from tall parents and likewise short plants that had been grown from short parents. In other words, selection was made in the two directions to see whether a new line could be established by such a method. The result was that, after five years of selection, the average height of the tall line plants for all the years was 88.5 centimeters and that for the short line was 88.1 centimeters. The average height of the parent lines for the same time was 94.2 and 68.0 centimeters, respectively. Altho there was an average difference of 28.2 centimeters in the height of the parents selected, there was practically no difference in the offspring from the two types of parents.

The results of the experiments just cited, and others like them, have been the means of changing the methods of practical plant breeding when dealing with self-fertilizing races such as wheat, oats, and the like. That is, it is now recognized that it is a waste of time and energy to continue to select within a line to improve a character or to breed one out.

[3]Reference by number is to "Literature Cited," p. 625.

A further important fact is that this point immediately emphasizes the importance of large numbers in making initial selections. Since the first selection is the important one, it is now recognized that a very large number of individuals should be selected. Formerly, selection experiments were begun with too few numbers. The effect of this change in method is noticed in the experimental work thruout the country. Where, formerly, many experiment stations had projects in plant breeding so outlined that new selections within the line were made each year, now most, if not all, of these projects are changed to conform with the present day knowledge. Here is an example, then, of how an original piece of research which was conducted not with the idea of its practical value but rather to learn whether selection in pure lines would effect a permanent change has had a profound effect in changing the methods of plant improvement.

Another contribution made by the general studies in plant genetics is that of the value of, and use that can be made of, hybridization in the improvement of plants. All of the studies that have had to do with inheritance of plant characters are an aid directly or indirectly. Directly, since they show us the mode of inheritance of many characters, and indirectly, since they open the way to new investigations. It is important that as much as possible should be learned regarding the inheritance of the various qualitative and quantitative characters of plants and also their linkage relations. While it may not be evident at once, it may develop later that knowledge of the behavior of one or more characters will be of considerable importance in its practical application.

Corn is one of the crops on which considerable genetic work has been done. This crop was used for some of the early research, and naturally, one examines this particular field to see what has been learned that is of importance in practice. A great amount of data has been accumulated as to the inheritance of many plant, ear, grain, and cob characters and the various linkages that exist between these different characters. All of this is very valuable. While some of this information has not been proven to be of practical importance, no one can say but that much of it later may be found to have considerable influence on the practical production of better strains of corn. It is evident that the more information available on the inheritance of the characters in corn the easier it will be to develop strains possessing certain special characters if a demand for such strains should arise. In this connection, it may be stated that considerable work has been done with seed ear characters in corn to indicate what types should or should not be selected.

Genetic work on corn, however, has led to a very important contribution to the knowledge of the effect of inbreeding in corn. As mentioned earlier in this paper, the early work with corn was planned without any reference to inbreeding. The invesitgations of East (2), Shull (3), Hayes (4), Jones (5), and others, however, have shown very definitely how by continuous self-fertilization the vigor is greatly reduced. The reduction in the size of plant is very rapid for the first two or three generations and then not so marked afterwards. Another feature of these inbred strains is that they tend to become more homozygous as the inbreeding continues. That is, the different plants from the same line are less variable than before inbreeding occurred.

However, when certain of these inbred strains were crossed with each other, it was found that the plants produced were very much more vigorous than were the parent varieties from which the inbred strains were selected. The plant is much larger than the parent variety and the yield of grain considerably increased. Another very important fact, is that these plants are more uniform than those of an ordinary variety. The yield of those crosses between the inbred strains may be increased, as Jones has shown, by again crossing the first crosses together or producing what he has called a "double cross." The yield of a cross between two inbred strains maintains itself fairly well for the first two years, then a gradual decrease occurs.

The increase in yield between certain inbred strains in this work is so marked that it seems possible that a method for the production of high yielding seed corn on a large scale can be developed. Further investigations are necessary to obtain inbred strains that will give the highest possible yield, since these, when crossed, should give the highest yielding strains. To be sure, it remains yet to be demonstrated whether seed can be produced cheaply enough and on a large enough scale to be worth while. Even tho there are certain obstacles in the way, the principle remains and no doubt some efficient means of putting it into practice will be developed.

The results of these experiments in corn may be found to be applicable to other normally cross-fertilized crops. It has already been shown by H. Nilsson (6) that the vigor of rye decreases by inbreeding and Myers (unpublished as yet) has found that with cabbage the vigor of the inbred strains decreases very rapidly. Whether the yields can be greatly increased by crossing inbred strains remains yet to be demonstrated.

Inheritance studies with oats furnish several examples of the contribution that genetics may make to the production of larger and

better crops. It is well recognized that, in some sections, earliness is a very important factor concerned with oat production. There are already at hand a number of early varieties of oats, some of which are very good yielders. At the same time, earlier strains than these may be desirable. As has already been suggested, there is little chance of obtaining such earlier strains by selecting from the early varieties already available. The matter may be approached, however, by means of hybridization. Noll (7) has shown that it is perfectly possible to produce earlier strains than those now obtainable by crossing certain varieties of early oats, and certain early varieties with mid-season oats. The first generation plants of certain crosses are usually earlier than either parent and some plants are produced in the second generation which are much earlier than the earliest of the parent varieties. These plants give rise in the third and later generations to very early lines. This work needs to be followed further in order to determine how these earlier strains yield; but the investigation has shown that, by crossing certain early strains, new earlier strains can certainly be produced.

Studies having to do with the inheritance of resistance and susceptibility to certain diseases of oats show the value of attacking such problems genetically as well as pathologically. The diseases that have received consideration are smut and rust. Reed (8) first made a rather extensive study of the behavior of different varieties of oats toward smut. In these investigations, he found considerable difference as to the amount of infection. Certain varieties were found that were very susceptible while others were found that were highly resistant. Some varieties did not develop any smut under the conditions of the experiment. Recently, Barney (9) has made a study of the inheritance of smut resistance in several crosses of oats. In these experiments Barney used some of the same varieties used by Reed. The tests on the varieties themselves gave very similar results to those obtained by Reed. Various crosses were made between varieties showing different degrees of susceptibility and varieties that are apparently resistant. The results obtained in the second generation were such as to indicate that resistance was dominant and that apparently resistance is due to one or more factors. Certain segregates were carried thru to the fifth generation and showed that those families which were resistant to smut in the third generation remained constantly so thru the fourth and fifth generations. The results of this investigation are such as to open the way to the development of desirable varieties of smut-resistant oats. The writer is aware that this disease is one that is readily controlled; but, never-

theless, the development of resistant strains is desirable and the introduction of such would soon have its effect on commercial oat growing.

The study of the inheritance of rust resistance in oats also shows the possibilities of developing resistant strains. The comparison of oat varieties (10) has shown that here also there is a great difference as to the reaction of different varieties to the development of the disease. These investigations brought out the fact that in general, with respect to crown rust (*Puccinia lolii avenae* McAlpine), there is a higher amount of infection in varieties of *Avena sativa* than in varieties of *Avena sterilis*. As regards stem rust (*Puccinia graminis avenae* Erikss. and Henn.) the greatest resistance is to be found among varieties of *Avena sativa*. When crosses are made between these susceptible and resistant varieties (11), it is found that resistance to stem rust is dominant and that apparently it is not linked with any undesirable characters. Hence, it seems perfectly possible to produce desirable types that are resistant. In connection with the studies on crown rust (12), the results are such as to indicate that susceptibility may be dominant, but that resistant types may be found. That is, in the case of the two important rusts, genetic investigations have shown that resistance is a heritable character and that new types may be produced which will be resistant to both rusts. It is readily clear how the study of the inheritance of these different diseases opens up the possibility of producing varieties resistant to all. Of course, it is recognized that there are different strains of such diseases as the rusts of plants and the like, and that a variety may be resistant to one strain and susceptible to another. This merely emphasizes the fact that in planning experiments for the production of resistant strains the studies must deal with the strains prevalent in the particular locality in which the experimenter finds his work.

The results obtained with the various species-crosses in oats also afford some knowledge as to what may be expected when it is planned to make certain kinds of crosses. Crosses between *Avena sterilis*, *Avena fatua*, *Avena nuda*, *Avena algeriensis*, and *Avena orientalis* are readily made and are fertile. In crosses between these and *Avena barbata*, *Avena brevis*, and *Avena strigosa*, however, different degrees of sterility are found; such that there is much less possibility of obtaining valuable types in such combinations.

Let us now consider briefly some of the genetic investigations that have been conducted with wheat that may have an influence on crop production. It is interesting to recall that, after the redis-

covery of Mendel's law, wheat was one of the first crops used to check up on the idea of segregation of characters. In fact, some work of this sort had been done with wheat even before Mendel's results were known to the public. It is also of interest to note that the first thoro genetic study of the inheritance of resistance and susceptibility to disease was conducted with wheat rust. Biffen (13) was the first to investigate this problem, followed soon after by Nilsson-Ehle (14). The investigation of this subject, has, however, been carried much further by workers in this country. The work of Stakman (15), Hayes (16), Melchers and Parker (17), and others has shown very definitely that there are certain varieties resistant to rust, and that this resistance is inherited. The fact is also shown that many different strains of rust exist and that some varieties of wheat are resistant to certain strains and susceptible to others. This complicates the breeding of resistant strains in that the work must be concerned with the strains to be found in the locality where the breeding work is being done. That is, this kind of work must be local in nature. Even so, it still is possible to develop resistant sorts for the various sections of the country. Should new strains of rust develop in any locality, new strains of wheat must also be developed. It is unfortunate that some of the most resistant types are not found among the common wheats but are in emmer and einkorn. These types when crossed with the common wheats do not give a large percentage of types suitable to cultivation. This fact, while an obstacle, is not insurmountable and suggests further work along this line. Perhaps it will be necessary to approach the desired result by several successive crosses. That is, it may be possible at any rate to obtain a fairly good type of resistant wheat from the first cross and then by crossing it again with a good wheat the desired type may eventually be reached. The results thus far are of sufficient importance to show that rust may be controlled or greatly lessened by the proper combination thru hybridization of yield on the one hand and resistance on the other.

The growing of wheat on the western coast is greatly affected by the presence of covered smut (*Tilletia tritici*) or bunt. The research work done by Gaines (18) on this problem shows how the resistance to this disease which is possessed by some varieties may be combined with the good qualities of other types and a new sort produced. There is no evidence that any linkage relations are present to render it impossible to produce a resistant form possessing the desired characteristics of high yield and quality. In fact, at least one valuable type is already in cultivation.

The quality, or texture, of wheat is one of the important characters to be considered and no doubt is the most important next to yield. Probably a slight loss in yield could be sacrificed for a fair increase in the quality. Environment plays a very important part in determining the quality of wheat. The better varieties of hard red wheat develop some kernels of poor quality ("yellow berries") nearly every year under ordinary conditions. Under very favorable conditions little yellow-berry is developed and the quality runs high. It is necessary that considerable work should be done on the question of quality both chemically and genetically, since it has not yet been definitely determined just what is involved in quality. Sufficient work, however, has been done with the quality of wheat to show that different strains of the same variety react differently to the same environment. It has also been shown that at least to a certain extent the tendency to produce kernels of high quality is inherited. Even tho this character is not inherited as definitely as some other plant characters, yet it shows the possibility of improvement along this line. The work of Freeman (19) and Bryan (20) on this question offers much encouragement to plant breeders to conduct further researches in this field.

The extensive studies that have been made on the hybrids between the different species of wheats show that certain combinations may readily be made and the different generations followed thru, while others lead to considerable sterility. It is clear that when species that differ widely from each other are crossed together a great many types are obtained which are of no practical value. This is partly due to sterility and partly due to the behavior of the various specific characters. An illustration of this is the case of crosses between emmer and some of the common wheat varieties. Good wheat plants do not occur with great frequency in the F_2 generation, yet, if a large number of F_2 plants are grown some good wheat types will appear.

It is also evident that with certain species, as with spelt, a number of the characters tend to be inherited as a group or, in other words, there is a certain linkage of characters such that it would be difficult to produce types from spelt crosses where these characters are inherited separately. Such characters are the glume character of spelt, brittle rachis, and shattering.

The study of the behavior of size characters in wheat and other plants shows the possibility of using the results of these investigations for further improvement of economic crops. The various size characters studied show that, in general, many of them are the result

of several factors and that when several of these dominant size factors are brought together the total size of a plant or plant character may be increased. For example, it has been found recently in the Cornell cereal investigations, that when two long-kernelled wheats are crossed together a type having longer kernels than either parent is obtained. This particular character probably does not have any practical value, yet the possibility of practical results obtained by the further study of size characters is suggested.

Many other lines of work could be outlined if time permitted; such as the various contributions that have been made to methods of obtaining better cotton varieties, the development of high-yielding, disease-resistant beans thru a knowledge of the inheritance of the factors concerned, the production of smooth-awned, high-yielding barleys thru the application of proper methods based on hereditary studies, the development of high-yielding strains of potatoes by the proper application of the method of selection, and so on, for many illustrations.

The foregoing experiments indicate only a few of the important fields toward which genetic research has been directed during the last few years. While considerable has been accomplished, there remains much to be done. Genetic research on characters dealing directly with yield or size characters has not proceeded far enough to shed much light upon the mode of inheritance of such characters. The question of yield alone is due to a complex of characters and this complex is so affected by varying environmental factors that it is difficult to attempt to study the heredity phase. This type of problem is one needing considerable attention before one can say whether it can or cannot be solved genetically in such a way that the mode of inheritance may be established. Certainly, much has been done on characters that indirectly affect yield and it is possible that further investigation will furnish us with information as to proper combinations to make in producing a better type of plant.

There are many problems as yet unsolved and it may not be amiss to mention some of them here. The question of the inheritance of earliness, especially with wheat and oats, is far from solved and if it can be determined that earliness could be combined with certain factors which influence high yield, the practical results would be of inestimable value. In sections where rust is of importance, a variety of wheat or oats that possessed high yield and was four or five days earlier than the sorts now at hand would add considerable to the value of the crop.

There needs to be considerable work done upon straw and stalk

characters, particularly with reference to stiffness, in order to determine the mode of inheritance and how better sorts may be produced. This is of great importance, especially with wheat and oats.

No work has yet been done upon the inheritance of drouth resistance and a study of the factors involved.

No investigations of any consequence (from the genetic standpoint) have been conducted with the root systems of plants. While such studies are extremely difficult, it may well be that from the standpoint of yield of plants the approach may be thru a study of the root systems. It is recognized that there are wide differences so far as root development is concerned and more information as to the inheritance of these different variations is desirable. This is especially important in alfalfa breeding.

The genetics of such crops as clover, soybeans, cowpeas, grasses, sorghums, and many of the vegetables, has not progressed far, chiefly on account of the difficulties involved and of the fact that the larger and more important crops have been chosen for the earlier investigations.

While the principles involved are the same for the different crops, nevertheless, it is important that these other crops be more thoroly analyzed genetically so that the mode of inheritance of many of their characters may be known. Then the work of improvement may proceed more intelligently.

While the work may be expensive and laborious, it seems highly important that as complete a genetic analysis as possible should be made of all the important field crops. This involves not only crosses between different cultivated varieties but also crosses between the different species. With corn, this work is fairly well along, altho far from complete. With oats, wheat and cotton, a good start has been made. With many of the other crops, however, only a small beginning has been made and much remains to be done.

Such genetic surveys are recommended for further study. Since the results of many of these investigations will affect large sections of the country, it may be advisable for the workers at the several stations to work on different phases of the problem. While the work is being conducted on these general surveys, there is no doubt but that there will be found, from time to time, certain types of plants of promise which should be put into commercial use. Thus, while the fundamental studies are being made, they will at the same time contribute some valuable types.

In conclusion, it may be stated that research in genetics has been of considerable importance in connection with the problems of plant

production. The methods to be followed in prosecuting such work have been developed and improved as the result of carefully-planned investigations. The principles of plant selection are now more thoroly understood, so that definite practical experiments in plant improvement may be planned, having regard for these principles.

The numerous experiments concerned with hybridization and a study of the resultant plants have furnished much information that can be put to practical use in developing (thru crossing) new types of plants. With certain crops there is now no occasion for making crosses and then attempting by continuous selection to develop the desired type. The mode of inheritance is known and should be used. Where it is not known genetic surveys should precede or go hand in hand with the practical improvement work.

LITERATURE CITED

1. JOHANNSEN, W. Ueber Erblichkeit in Populationen und in reinen Linien. Gustav Fischer, Jena. 1903.

2a. EAST, E. M. Inbreeding in corn. *In* Conn. Agr. Exp. Sta. Rept. for 1907. pp. 419–428. 1908.

2b. ——— The distinction between development and heredity in inbreeding. *In* Am. Nat. 43:173–181. 1909.

3a. SHULL, G. H. The composition of a field of maize. Rept. Am. Breeder's Assoc. 4:296–301. 1908.

3b. ——— A pure line method of corn breeding. Rept. Am. Breeder's Assoc. 5:51–59. 1909.

4. HAYES, H. K. and JONES. D. F. The effects of cross-and self-fertilization in tomatoes. Conn. Agr. Exp. Sta., Part V of Ann. Rept. for 1916, pp. 305–318. 1917.

5a. JONES, D. F. Dominance of linked factors as a means of accounting for heterosis. *In* Proc. Nat. Acad. of Sciences 3:310–312 and also *in* Genetics 2:466–479. 1917.

5b. ——— and HAYES, H. K. Increasing the yield of corn by crossing. Conn. Agr. Exp. Sta., Part V of Ann. Rept. for 1916, pp. 323–347. 1917.

5c. ——— The productiveness of single and double first generation corn hybrids. *In* Jour. Amer. Soc. Agron., 14:242–252. 1922.

6. HERIBERT-NILSSON, N. Populationsanalysen und Erblichkeitsversuche uber die Selbststerilitat, Selbstfertilitat und Sterilitat bei dem Roggen. Zeitschrift fur Pflanzenzuchtung, Band IV, Heft 1, Pp. 1–44. 1916.

7. NOLL, C. F. A study of inheritance of earliness in certain *Avena* crosses. (Thesis) 1923.

8. REED. G. M. Varietal resistance and susceptibility of oats to powdery mildew, crown rust, and smuts. Mo. Agr. Exp. Sta. Res. Bul. 37. 1920.

9. BARNEY, A. F. A Study of the inheritance of smut resistance in crosses between varieties of *Avena sativa* and *Avena sterilis*. (Thesis) 1923.

10. PARKER, J. H. Greenhouse experiments on the rust resistance of oat varieties. U. S. Dept. Agr. Bul. 629. 1918.

11a. GARBER, R. J. A preliminary note on the inheritance of rust resistance in oats. *In* Jour. Amer. Soc. Agron. 13:41–43. 1921.

11b. ——— Inheritance and yield with particular reference to rust resistance and panicle type in oats. Minn. Agr. Exp. Sta. Tech. Bul. 7. 1922.

12. PARKER, J. H. A preliminary study of the rust resistance of oats. *In* Jour. Amer. Soc. Agron. 12:23–38. 1920.

13. BIFFEN, R. H. Studies in the inheritance of disease resistance. *In* Jour. Agr. Sci. 2:109–128. 1907.

14. NILSSON-EHLE, H. Kreuzungsuntersuchungen an Hafer und Weizen. Lunds Universitets Arsskrift. N. F. Afd. 2, Bd. 7, Nr. 6. 1911.

15a. STAKMAN, E. C., and PIEMEISEL, F. J. A new strain of *Puccinia* (Abst.). *In* Phytopath. 7:73. 1917..

15b. ——————— and LEVINE, M. N. Plasticity of biologic forms of *Puccinia graminis*. *In* Jour. Agr. Res. 15:221–250. 1918.

15c. ———, PARKER, J. H., and PIEMEISEL, F. J. Can biologic forms of stem rust on wheat change rapidly enough to interfere with breeding for rust resistance? *In* Jour. Agr. Res. 15:111–124. 1918.

15d. ———, LEVINE, M. N., and LEACH, J. C. New biologic form of *Puccinia graminis*. *In* Jour. Agr. Res. 16:103–105. 1919.

16a. HAYES, H. K., and STAKMAN, E. C. Wheat stem rust from the standpoint of plant breeding. (Paper read at the Annual Meeting of the Western Canadian Society of Agronomy held at Winnipeg, Manitoba, December 27, 28, 29, 1921.)

16b. ———, PARKER, J. H., and KURTZWEIL, CARL, Genetics of rust resistance in crosses of varieties of *Triticum vulgare* with varieties of *T. Durum* and *T. Dicoccum*. *In* Jour. Agr. Res. 11:523–542. 1920.

16c. ——— and AAMODT, O. S. A study of rust resistance in a cross between Marquis and Kota wheats. *In* Jour. Agr. Res. 24:997–1012. 1923.

17. MELCHERS, L. E., and PARKER, J. H. Rust resistance in winterwheat varieties. U. S. Dept. Agr. Bul. 1046. 1922.

18. GAINES, E. F. The inheritance of resistance to bunt or stinking smut of wheat. *In* Jour. Amer. Soc. Agron. 12:124–131. 1920.

19. FREEMAN, G. F. Producing bread making wheats for warm climates. *In* Jour. Heredity. 9:211–226. 1918.

20. BRYAN, W. E., and PRESSLEY, E. H. Plant breeding. Ariz. Agr. Exp. Sta. Ann. Rept. for 1920, pp. 480–483. 1921.

7. EDAPHICS (SOILS RESEARCH)[1]

J. G. Lipman[2]

Metaphorically speaking, the soil has many dark corners. To bring light to these corners appeal for help must be made to the sciences that have already done so much in substituting understanding for empiricism. Certain leading questions must be asked concerning the fundamental significance of soil practices like tillage, drainage and irrigation, liming, alkali reclamation, green manuring, inoculation, the control of objectionable microorganisms and insects, and the application of manures and fertilizers. If these questions are intelligently put, there will be found in the answers the boundaries of present knowledge and of ignorance. Scientists will be better prepared then to organize the resources of learning and experience for a successful expedition into the unknown.

The soil is thought of as a culture medium of microorganisms and higher plants. Indeed, it is a *collection* of culture media, for many organisms of diverse habits find in it a congenial environment. One may picture to himself, as he thinks of the soil, a loose mass of rock material well advanced on the road of disintegration. The soil particles range in size from small pebbles and coarse grains of sand to the finest of clay. Mingled with these are fragments of plants, insects, mycelia, protozoa, and bacteria. Many small particles are cemented together into aggregates of varying size. The simple and compound grains are covered with a deposit of colloidal material, the seat of important chemical and biological changes. The spaces between the soil grains are partly filled with a mixture of gases, most of it nitrogen. In the moisture films about the soil grains, a vast microbial population is constantly building and destroying, while the root hairs of plants are in intimate contact with the moisture films and the particles themselves. In fact, it is claimed by Comber that the colloidal matter of the root hairs and of the soil grains represents, in effect, a single system.

By way of illustration, let us try to fit into this picture anyone of the more common soil practices. The operations of tillage may well serve the present purpose. Tillage disturbs the relation of air and water in the soil. It affects the exchange of gases between the soil and atmosphere. It modifies the supply of water and the soil tem-

[1]Paper read as a part of the symposium on "Research Fundamental to the Solving of Crop-plant Problems," at the meeting of the Society held in Cincinnati, December 28, 1923.

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perature. It influences in a more or less far-reaching way the activities of microorganisms. These, in turn, affect the rate of solution of mineral matter, the decomposition of organic residues and the concentration and reaction of the soil solution. Root development and crop growth are influenced by these changes, and reciprocal effects make themselves felt in so far as the consumption of water and of plant-food becomes more intense. Obviously, therefore, a critical study of tillage and of its fundamental significance must involve the use of methods employed in a similar study of other soil practices. If this conclusion is sound, stress should be laid on the deeper rather than the more superficial aspects of soil research. There should be drawn first the broad outlines of the problems in soil physics, soil chemistry and soil biology, in the certain knowledge that specific applications will be facilitated and that the interpretation of research data will be made less difficult.

The broad problems of soil science must necessarily overlap, since the physical, chemical, and biological phenomena are more or less intimately related. Nevertheless, it will be convenient to follow these broad divisions in a consideration of soil research questions. In the domain of soil physics, there is need for systematizing and expanding present knowledge concerning the interplay of forces that have to do with the genesis of soils. The research projects relating to this question should be so organized as to allow of a well-balanced investigation of the relative importance of solution and oxidation in the weathering of rock material. The influence of the parent rock, as well as that of season and climate, should be taken under consideration. A critical study of the problem should also deal with the nature and amount of the material removed through drainage and oxidation. The systematic analysis of drainage and surface waters would be important in this connection. A mineralogical and chemical study should be made of the rock residues at different stages of weathering and these should be accompanied by studies of texture and structure. Much work has already been done in this field, but wide gaps exist in present knowledge of the subject. Encouragement should be given to the efforts of some individual or group of individuals towards completing and classifying the information on the factors which concern the genesis of soil and the relation of these to the development of vegetation.

Science is rich in the possession of a mass of data concerning the movement of water in soils. The factors of mechanical composition, structure, chemical composition, the velocity and direction of air currents, the character of the subsoil, methods of cropping, tillage and

fertilization have all been investigated in their relation to the retention and movement of water in soils. But, here again, our records show frequent gaps. Too much of the information is specific rather than general. Too large a part of the information concerning the capillary rise of water has been derived from laboratory rather than field study. The broader and more far-reaching interpretations must come from a far-flung study of biological, climatic, seasonal and ecological factors. Investigations of soil temperature exhibit the same defects. It is not possible to make definite statements concerning the range of soil temperature as affected by altitude, latitude, exposure, season, color, organic matter content, texture, structure, drainage, irrigation, tillage, fertilization, etc. Neither is it possible to summarize our knowledge of the soil solution for the purpose of establishing conclusions of wide application. How is the nature of the soil solution affected, under a wide range of climatic and seasonal conditions, by the nature of the parent rock, by the amount and distribution of rainfall, by extremes and means of soil temperature, by exchange of gases between the soil and the atmosphere, by quantitative and qualitative relations among soil microorganisms, by tillage processes, by cropping, or the application of lime, manures and fertilizers.

Investigations on the nature of soil gases have revealed important facts concerning the composition of soil air, its movement and its relations to the physical, chemical and biological characteristics of the soil. But, once again, it must be confessed that the information here is too specific and fragmentary. Much careful research will be needed to round out our knowledge of the part that texture, structure, temperature, water-supply, pressure, as well as microbiological activities, cropping, tillage and fertilization, may play in the formation and movement of soil gases.

When knowledge concerning soil water, air and heat is made more exact, it will be possible to apply it more effectively toward the solution of problems that have to do with the economics of crop production. It is apparent, for example, that the better definition and interpretation of phenomena of soil physics would make clear the character of root penetration and the influence on root penetration of texture, structure, reaction, and the concentration of the soil solution. Similarly, the loss, conservation, and utilization of soluble salts, including those derived from fertilizers, could be better controlled through an understanding of the fundamental relations of water, air, and heat in soils. This will also hold true of other soil practices directly or indirectly influenced by the quantity and quality

of the soil solution. In this connection, it may not be amiss to point out that there is need for a systematic study of the influence exerted by heavy tillage machinery, especially that operated by mechanical power, on the structure of the soil grains. There is need, likewise, of comprehensive investigations on the significance of the concentration of the soil solution from the standpoint of plant physiology. Water culture experiments have already clarified this field of study. Nevertheless, the general relations established by plant physiologists are necessarily modified by variations in the physical, chemical and biological properties of soils as they exist under a wide range of field conditions.

In the domain of soil chemistry there has been acquired in recent years much information of importance. The chemical structure of soil silicates; the basic exchange in soils; the nature of soil acidity; the buffer action of soils; soil colloids and their character, have all come under the careful scrutiny of able and well-trained investigators. Recent studies have dealt with oxidation and reduction processes in soil. They have dealt, likewise, with the nature and transformation of organic matter and with the soil solution and its transformation in the light of the newer knowledge on the physiology of microorganisms and of our deeper insight into the character of solutions and of colloids. One need not go far afield for suggestions as to the application of the newly accumulated knowledge in behalf of the more successful and economic production of crop-plants. Reference may be made here, by way of example, to the great mass of data which has been gathered on the subject described, according to circumstances, under the terms "soil acidity," "lime requirement" or "the supply of basic material in soils." If nothing more, it has become apparent that scientists are far from understanding the relations involved. The factors of hydrogen and hydroxyl-ion concentration, the toxicity of aluminium and iron salts and the lack of calcium, for certain crops at least, are barely emerging into a clearer perspective. The relations of these to one another and to the character of the crops grown and of tillage and fertilizer practices will be established more clearly in the years to come. It will be possible then to deal more effectively with alkali reclamation problems and the use of basic and acid fertilizers.

The soil biologist is still engaged in finding new tools and in sharpening the old ones for a more vigorous attack on the problems before him. A conception of the soil as a collection of culture media has served to clarify our vision. The writer proposed many years ago the study of mixtures of known species of soil microorganisms. Such

synthetic floras, observed under controlled conditions, should be a means of giving a better understanding of associative action and competition among soil microorganisms and their colonization on individual soil particles and root hairs. A systematic study of the factors of heat, water, oxygen pressure, the soil solution and its modification by soil treatment, would be in order. The research in this direction thus far accomplished is far too fragmentary to justify general conclusions. Moreover, it should not be forgotten that the soil is a suitable culture medium for a host of insects, nematodes, and other organisms whose activities react on the soil microflora as well as on the welfare of cultivated plants. Our knowledge of soil biological processes would find wider application if it were ample enough to justify answering with more assurance certain specific questions. Here and there reference is made to investigations on the effect of tillage on soil microorganisms. The number of references concerning the effect of lime and of farmyard manure is greater. More knowledge is available on the influence of fertilizer treatment, of green manures, of rotations, and of specific crops. A very considerable amount of study has been given to the subject of partial soil sterilization. The same is true also of soil inoculation. But, when all is said and done, no one is at all ready to describe clearly and conclusively how soil microorganisms influence, under any given set of conditions, the development of plants. No one is ready to evaluate with exactness the conditions that make, on the one hand, for retardation of plant growth through the competition of microorganisms, and, on the other, for stimulated plant growth because of a favorable balance of microbiological activities.

It is not intended to trespass here on the problems of the plant physiologist. It is difficult, however, to dissociate certain questions that are common to soil science and to plant science. One may speak of the limiting factors in crop production. These may be physical, chemical or biological. In studies of the soil solution, one must reckon with the influence exerted on the soil solution by the crops. There must be considered the partial substitution of potassium by sodium, or of phosphorus by silicon, as a factor in the economic production of crops. One cannot overlook the significance of the quantity and quality of the salts dissolved in soil water in determining the rate of growth, maturation and market value of food crops. In applying fertilizers, the factor of luxury consumption must be taken into account. It must be recognized that beyond a certain point readily soluble fertilizers applied locally tend to make the soil solution so strong as to inhibit seed germination and early growth.

Certain fertilizers contain small amounts of boron and of other constituents that are toxic to plants. The soil chemist is beginning to look into the significance of manganese, titanium, fluorine, and other constituents that were at one time entirely ignored in the analytical study of soils. The relative values of different compounds of phosphorus, nitrogen, potassium and calcium are being considered more carefully, while the supply of carbon dioxide in the atmosphere is being studied as a possible limiting factor under some conditions of intensive plant production. The quantity and quality of nitrogen salts and the supply and availability of potassium are being studied in their relation to disease resistance in cultivated crops. Is there a definite relation between soil type and the color and flavor of fruits and vegetables? What relation, if any, is there between soil composition and the content of vitamines in crops? To what extent is stiffness of straw in cereals determined by the variety on the one hand and the chemical nature of the soil on the other? Legumes are depended upon for at least a part of the fixed nitrogen in soils. But how much nitrogen do legumes fix under different conditions; and how much of the nitrogen in legumes is derived from the air and how much from the soil? Evidence is not lacking that disease resistance is not infrequently influenced by soil conditions. What is the nature of these influences? Water culture experiments have taught us much about plant food ratios and concentrations. How are these affected by soil type? What is the best source of nitrogen for different crops? Are fractional applications more effective than single applications from the point of view of quality and crop yields? It is important to know more about the circulation of sulphur and the supply of it in soils. New nitrogenous and phosphatic fertilizers are constantly appearing and their relation to crops and soils must be known. In every cropping system attempts are made to balance the losses and gains of organic matter, but knowledge of the subject is defective because it is not possible yet to understand all of the factors concerned.

Many other questions might be asked here and many problems suggested. It is not the purpose of the writer to trespass on your time unduly, but rather to pave the way for a discussion of a subject which in its varied aspects must make a strong appeal to a large number of investigators.

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DEPRESSION OF CHECK-ROW YIELDS BY ADJOINING HIGH YIELDING PLOT ROWS IN POTATOES[1]

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That competition occurs in adjacent plots of potatoes has been established by Meyers and Perry (3)[3] and by Stewart (4 and 5), although the work of Brown (1) indicates that under certain conditions, at least, yields are not appreciably influenced by competition between one row plots. In this connection, Meyers and Perry note that "with respect to the effect of competition in potatoes, there is very little to be found in the literature." In some recent work by the writer, some harvest weights were obtained in such a manner as to give a little further evidence on this point. Since the work will not be continued along the same lines, in the future, it seems best to report the results at the present time.

METHODS USED

The work under consideration was an experiment dealing with size of potato seed piece laid out in cooperation with one of the leading potato growers near Farmingdale, N. J., in which it seemed desirable to use single row plots with check plots on either side. Four sizes of seed piece, one-half ounce, one ounce, one and one-half ounce, and two ounce, were used. Each row was 570 feet in length and trimmed at harvest to 500 feet. Plots were replicated to give three rows of each size, making twelve plot-rows and thirteen check-rows. Plants were spaced thirteen inches apart in thirty three-inch rows and all rows fertilized with the regular fertilizer distributor, using the same

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[2]Agronomist.

[3]Reference by number is to "Literature Cited," p. 635.

quantities and kind of fertilizer as that used for the remainder of the field, i. e., 1800 pounds per acre of a 4-8-5 mixture, The rows extended across the apparent soil variation, although the field could be considered as being above average in uniformity. The details of arrangement, as well as the average number of stems per plant for the various plots have been previously reported. (2). The results of counts of the average number of stems per plant, six weeks after planting, are shown in Table 1.

TABLE 1.—*Average number of stems per plant with various sizes of seed piece.*

Size of seed piece	Dayton plots	Farmingdale plots
Check (approximately 7/8 ounces)	1.6 ± .988	1.7 ± .476
One-half ounce........................	1.28 ± .591	1.475 ± .322
One ounce............................	1.84 ± .625	2.1 ±1.40
One and one-half ounce.................	2.74 ±1.16	3.15 ± .584
Two ounce............................	3.54 ±1.01	3.7 ±1.96

The counts are based on averages of 50 hills each. The increase in numbers of stems with increase in size of seed piece is seen to be slight and scarcely significant. The variability within groups is perhaps due in part to variation in number of eyes per seed piece, since the seed was cut to equal size without regard to number of eyes. The Dayton counts are included for purposes of comparison because of the slight increase which was found in both tests.

RESULTS

The effect of the competition between the check rows and the adjoining plot rows can be seen in Table 2, in which there have been assembled and averaged the yields of all check plots lying between the plots indicated and in comparison with the yields of the adjoining plot rows.

TABLE 2.—*Average yield of check rows and plot rows adjoining either side.*

Location of check rows	Check yields[a] lbs. per 100 ft.	Plot rows	Average yields of adjoining plot rows lbs. per 100 ft.
Between ½ and 1 oz. rows	67.53 ±2.854	½ and 1 oz.	57.62 ±2.351
Between 1 and 1½ oz. rows	65.50 ±4.182[b]	1 and 1½ oz.	65.53 ±1.886
Between 1½ and 2 oz. rows	60.53 ±2.068	1½ and 2 oz.	69.27 ±1.927

[a]Harvest weights are averages of fifteen 100-foot blocks of row in each case.
[b]In harvesting this series portions of two blocks were weighed as one by error. Data is otherwise apparently as consistent as the other series.

As it is to be expected, the depression in yield of check rows is slight, but is never the less sufficient to be of interest. The yields of the individual rows are given in Table 3.

Correlating the check yields with the average yields of the adjoining rows shows $r = -.6526 \pm .1914$, a significant negative

correlation. A regression coefficient of — .56 indicates the average depression of check yields under the conditions of this experiment.

TABLE 3.—*Comparative yields of check rows and adjoining plot rows.*

Plots westerly side of check rows: Plot no.	Size of seed	Row yield 500-ft. row	Check yield lbs. per 500-ft. row	Plots easterly side of check rows: Plot no.	Size of seed	Row yield lbs. per 500-ft. row	Average yields Rows adjoining check plots per 500-ft. row
2	½ oz.	270	356	4	1 oz.	325.5	297.75
10	½ oz.	244	348	12	1 oz.	307	275.50
18	½ oz.	273	309	20	1 oz.	309	291.00
4	1 oz.	325.5	333	6	1½ oz.	330	327.75
12	1 oz.	307	337.5	14	1½ oz.	343.5	325.25
20	1 oz.	309	312	22	1½ oz.	351	330
6	1½ oz.	330	294	8	2 oz.	360.5	345.25
14	1½ oz.	343.5	323	16	2 oz.	338	340.75
22	1½ oz.	351	291	24	2 oz.	355	353
Average..................			322.61				320.69

CONCLUSIONS

The depression of the check yield by the adjoining high yielding plot rows, though slight, seems to indicate that competition exists in the cases cited. This is indicated by the high negative correlation coefficient — .6526 ± .1914 as found by comparing the respective check yields with the average of the adjoining plot yields. The plots consisted of 500-foot rows replicated to give a total of three plots of each treatment or a total of 1500 feet of row. The results are for but a single year.

LITERATURE CITED

1. BROWN, B. A. Plot competition with potatoes. *In* Jour. Amer. Soc. Agron. 14:257–258. 1922.
2. MUSGRAVE, G. W. Report, Department of Agronomy, N. J. Agr. Exp. Sta. 1923.
3. MYERS, C. H. and PERRY, F. R. Analysis and interpretation of data obtained in comparative tests of potatoes. *In* Jour. Amer. Soc. Agron. 15:239–253. 1923.
4. STEWART, F. C. Missing hills in potato fields; their effect upon the yield. N. Y. (Geneva) Agr. Exp. Sta. Bul. 459. 1919.
5. STEWART, F. C. Further studies on the effect of missing hills in potato fields and on the variation in the yield of potato plants from halves of the same tuber. N. Y. (Geneva) Agr. Exp. Sta. Bul. 489. 1921.

ENVIRONMENTAL FACTORS AFFECTING THE PROTEIN AND THE OIL CONTENT OF SOYBEANS AND THE IODINE NUMBER OF SOYBEAN OIL[1]

ROBERT W. STARK[2]

The rapidly increasing use of soybeans, both as a feed for livestock and as a source of vegetable oil, has resulted in a very general desire for information concerning the composition of soybeans and the factors which affect the relative proportion of their different constituents. Many analyses, made by various investigators, have shown that varieties differ in their composition; that is, that there are differences inherent in the varieties. But it frequently has been observed, also, that the same variety, when grown during different years or in different environments the same year, varies materially in composition. Hence chemical composition may be affected by the influence of environmental factors on the physiological processes of the plant.

Previous work conducted by other investigators, as well as that done by the writer, indicated that certain kinds of soil treatment constitute one of the most important factors affecting the composition of soybeans. According to Fellers (1)[3] of the New Jersey Agricultural Experiment Station, applications of lime to the soil decreased the oil content of the soybeans in proportion to the amount of lime applied. Small applications of acid phosphate materially increased it, especially when 1000 to 2000 pounds of lime were also applied. Fertilization with potassium resulted in a slight decrease in oil content. Lipman and Blair (3) of the New Jersey Station grew soybeans on limed and unlimed plots. They found that liming such soil caused an increase in the yield of seeds and that they contained a higher percentage of nitrogen. Later work conducted on limed and unlimed plots confirmed the earlier results.

The beans grown on the soil fertility fields of the Illinois Agricultural Experiment Station afforded excellent material for further investigation of this phase of the subject.

FERTILIZER TREATMENT AND SOIL TYPES USED

A four-year rotation has been followed on all of these fields, although the kinds of crops grown have not been the same in all cases.

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[1]Contribution from the Department of Agronomy, Illinois Agricultural Experiment Station, Urbana, Ill. Received for publication August 4, 1924.

[2]Associate in Crop Production.

[3]Reference by number is to "Literature Cited", p. 645.

On all but one of them, the effect of both the grain system and the livestock system of farming has been demonstrated. In the grain system of farming, crop residues including the cornstalks, straw, clover chaff, soybean chaff, and green manure crops have been plowed under. In the livestock system, an amount of manure equal in weight to the total amount of the crops removed has been applied. The mineral fertilizers have consisted of: (1)ground limestone, applied at the rate of four tons per acre for the initial application and two tons each succeeding fourth year; (2) raw rock phosphate applied at the rate of one ton per acre each fourth year; and (3) potassium in the form of kainit applied once in four years at the rate of 800 pounds per acre. These fields have all been in cultivation for a number of years, so that the effect of soil treatment is cumulative.

Four different types of soil are represented by these fields. The soil of the Carthage Field is a brown silt loam of the Upper Illinoisan Glaciation. Grain crops in general have responded to organic manures and limestone. Phosphorus and potassium in addition to organic matter and limesone have given small additional increases. The Odin field is in the Lower Illinoisan Glaciation. The soil is a gray silt loam on tight clay. Soils of this class are normally quite acid and need lime and organic matter. Phosphorus and potassium have also given increased yields of crops on this field, particularly those of wheat. Plots 101-105 are not tile drained, while plots 106-110 are tile drained. The Raleigh field represents the yellow-gray silt loam, timber type of the Lower Illinoisan Glaciation. The soil is acid and deficient in organic matter. Phosphorus and potassium, in addition to organic matter and lime, have given increased yields of crops. The Sparta field is a gray silt loam on tight clay, timber type. It also is located in the Lower Illinoisan Glaciation. The soil is acid and responds in a marked degree to applications of organic matter and limestone. Applications of phosphorus have caused no improvement in the yield of cereal crops, but potassium has increased the yield.

The soil treatment practiced on each plot of these different fields together with the yields of beans and their composition are shown in Table 1.

It will be observed that manure and lime and residue and lime have been the fertilizing materials which have brought about the greatest increase in yield of beans. Phosphorus, in addition to manure and lime and residues and lime has given further increase on four of the plots, while on the other four there was a decrease in yield. Potassium, in addition to residues, limestone, and rock phosphate, gave a slight increase on four of the five plots so treated.

TABLE 1.—*Showing the effects of soil treatment upon yields and composition of soybeans grown in different localities and on different types of soil.*

Where grown	Plot No.	Soil treatment[a]	Bu. seed per acre	Percentage protein	Percentage oil	Pounds protein per acre	Pounds oil per acre	Iodine number of oil
Carthage.....	1	None	31.2	42.80	19.85	721.1	334.4	133.1
	2	M.	27.1	43.42	19.68	635.4	288.0	133.3
	3	M. L.	30.4	45.48	18.58	746.6	305.0	131.5
	4	M. L. P.	28.8	46.19	18.29	718.3	284.4	131.3
	5	None	23.6	42.90	20.24	546.7	257.9	130.8
	6	R.	24.3	40.40	20.71	530.1	271.8	131.7
	7	R. L.	29.7	45.74	18.70	733.6	299.9	132.8
	8	R. L. P.	28.2	45.63	18.66	694.9	284.1	130.9
	9	R.L. P. K.	29.2	46.09	18.49	726.7	291.6	131.0
	10	None	22.8	42.01	20.08	517.2	247.2	131.8
Raleigh	1	None	6.9	39.86[b]	20.74[b]	148.5	77.3	
	2	M.	11.0	37.23	21.61	221.2	128.4	133.4
	3	M. L.	21.2	42.30	19.22	484.3	220.0	134.5
	4	M. L. P.	23.6	44.42	19.26	602.0	245.4	132.5
	5	None	9.2	39.86[b]	20.74[b]	198.0	103.0	
	6	R.	12.7	37.68	21.14	258.4	145.0	141.0
	7	R. L.	20.3	43.31	19.55	474.8	214.3	130.8
	8	R. L. P.	21.8	43.12	18.87	507.6	222.1	132.4
	9	R.L.P.K.	24.1	42.29	18.86	550.4	245.4	133.8
	10	None	13.6	39.86[b]	20.74[b]	292.8	152.3	133.3
Sparta......	1	None	9.3	34.88[c]	20.89[c]	175.2	104.9	
	2	M.	12.0	38.52	19.93	249.6	129.2	136.2
	3	M. L.	25.7	41.72	19.23	579.0	266.9	137.6
	4	M. L. P.	24.5	42.00	18.82	555.7	249.0	136.7
	5	None	3.5	34.79	20.79	65.8	39.3	134.0
	6	R.	7.3	36.18	20.68	142.6	81.5	136.2
	7	R. L.	22.7	43.51	18.66	533.3	228.7	134.5
	8	R. L. P.	25.7	44.37	18.49	615.8	256.6	135.2
	9	R.L.P.K.	21.7	43.27	18.71	507.0	219.2	136.4
	10	None	5.0	34.97	20.98	94.5	56.6	136.5
Odin (untiled)	1	None	18.4	41.52	19.51	412.5	193.9	137.1
	2	R.	18.2	39.79	20.03	391.1	196.9	135.3
	3	R. L.	20.7	45.28	18.05	506.1	201.8	132.8
	4	R. L. P.	18.8	45.66	17.77	463.5	180.4	134.3
	5	R.L.P.K.	23.8	43.34	18.43	557.0	236.9	135.4
(tiled)...	6	None	15.4	40.31	19.77	335.2	164.4	135.0
	7	R.	18.9	41.74	19.15	426.0	195.4	139.7
	8	R. L.	22.5	44.31	18.14	538.4	220.4	136.5
	9	R. L. P.	24.3	44.37	18.43	582.2	241.8	135.1
	10	R.L.P.K.	27.0	40.82	19.23	595.2	280.4	135.6

[a]M. stands for manure; M. L., for manure and lime; M. L. P., for manure, lime and rock phosphate; M. L. P. K., for manure, lime, rock phosphate and kainit; and R, for crop residues.

[b]No samples received for Plots 1 and 5. Substituted the precentages of protein and oil obtained for 10.

[c]No sample received for Plot 1. Substituted the average percentages of protein and oil obtained for Plots 5 and 10.

There appears to be some correlation between the yield of beans and their composition, an increase in the yield frequently being coincident with an increase in protein content and a decrease in the oil.

There is a very marked correlation between soil treatment with limestone and the composition of the seed. Accompanying applications of limestone, there is an increase in the protein content. Phosphorus has still further increased the protein content of the beans grown on six of the eight plots. Potassium gave an increase by a fraction of a percent in one instance. The beans from the other plots showed a decrease in protein content.

The effect of soil treatment upon the oil content of the beans was found to be practically the reverse of that upon the protein. This is particularly true with reference to applications of limestone. In every instance, applications of limestone were followed by a decrease in the content of oil. Phosphorus has, in most cases, still further decreased the percentage of oil, while potassium has shown a slight increase. The gain or loss of oil and protein resulting from the different soil treatments is given in Tables 2 and 3.

TABLE 2.—*Showing the gain or loss in percentage content of protein resulting from the several ingredients used in fertilizing the soil.*

Soil treatment	Carthage	Raleigh	Sparta	Odin		Average
				Untiled	Tiled	
None...........						
M..............	+ .62	—2.63	+3.64			+ .54
M. L...........	+2.06	+5.07	+3.20			+3.44
M. L. P.........	+ .71	+2.12	+ .28			+1.04
None...........						
R..............	—2.50	—2.18	+1.39	—1.73	+1.43	— .72
R. L...........	+5.34	+5.63	+7.33	+5.49	+2.57	+5.27
R. L. P.........	— .11	— .19	+ .86	+ .38	+ .06	+ .20
R. L. P. K.......	+ .46	— .83	—1.10	—2.32	—3.55	—1.47

TABLE 3.—*Showing the gain or loss in percentage content of oil resulting from the several ingredients used in fertilizing the soil.*

Soil treatment	Carthage	Raleigh	Sparta	Odin		Average
				Untiled	Tiled	
None...........						
M..............	— .17	+1.07	— .96			— .02
M. L...........	—1.10	—2.39	— .70			—1.40
M. L. P.........	— .29	+ .04	— .41			— .22
None...........						
R..............	+ .47	+ .40	— .11	+ .52	— .62	+ .13
R. L...........	—2.01	—1.59	—2.02	—1.98	—1.01	—1.72
R. L. P	— .04	— .68	— .17	— .28	+ .29	— .18
R. L. P. K.......	— .17	— .01	+ .22	+ .66	+ .80	+ .30

In explanation of these tables, it may be stated that at Carthage the beans grown on the plot which received manure only contained 0.62 percent more protein than did those from the adjacent unfertilized plot. At Raleigh, there was a loss of 2.63 percent of protein where manure was used; while at Sparta, the manure gave a gain of 3.64 percent. The average gain for manure over no manure on the

three fields was 0.54 percent. Again, at Carthage, where limestone was applied in addition to manure, the beans contained 2.06 percent more protein than did those produced on the plot receiving manure only. At Raleigh, the gain amounted to 5.07 percent and at Sparta the gain was 3.20 percent. As an average of the results from the three fields, the beans produced on the plots which received lime in addition to manure were found to contain 3.44 percent more protein than did those from plots treated with manure only.

Since it has been shown that lime causes a decided decrease in the percentage of oil in soybeans, the question at once arises whether this represents a real or only an apparent loss; whether there has been a smaller amount of oil per acre synthesized where lime is applied. In Table 1, there is shown the number of pounds per acre of protein and of oil calculated from the yields and from the percentages of protein and of oil found. The percentages given in the table are on the water-free basis. The yields of beans were calculated from the weights of the beans as they came from the bean huller. It is assumed that they uniformly contained ten percent of moisture at that time and the pounds of protein and of oil were calculated on that basis. It is evident that there is a decrease in the percentage of oil incident to liming the soil; still the beans which grew on the limed land were so much more productive that the total amount of oil elaborated and stored in the seed was greatly increased.

Expressed in number of pounds of oil gained or lost by the various soil treatments, it was found that manure gave an average increase of oil over no treatment amounting to 6.7 pounds per acre, while residues gave an average increase over no treatment of 26.4 pounds per acre. Limestone added to manure gave a further increase of 82.2 pounds per acre, and when applied with residues, the average gain for the limestone was 54.9 pounds per acre. Phosphorus applied in addition to manure and limestone resulted in an average loss of 4.3 pounds of oil per acre and phosphorus in addition to residues and limestone caused a gain of 2.7 pounds per acre. When potassium was added to residues, lime and phosphorus, there was an average loss of oil amounting to 2.8 pounds per acre.

EFFECT OF GEOGRAPHICAL LOCATION UPON THE COMPOSITION OF SOYBEANS

It has been stated above that the same variety of beans grown in different localities may vary in composition due to environment or to local seasonal conditions. Piper and Morse (5) report an instance in which four varieties of soybean seed imported from Manchuria were distributed to a number of experiment stations. Analysis of the re-

sulting crops showed that when grown under varying environmental conditions the beans differed greatly in composition within the variety. Garner *et al* (2) grew soybeans in plots under controlled conditions. Different types of soil were used. The conclusion was reached that the effect of soil type upon the composition of the beans is subject to variation and that seasonal conditions play a more important rôle than does soil type.

As an incident to another line of investigation, samples of four different varieties of beans were obtained from different sections of the state of Illinois. The seed from which each of these varieties of beans were grown had been distributed the previous spring by the Illinois Agricultural College. On analysis, these samples yielded the data shown in Table 4.

TABLE 4.—*Variation in the composition of soybeans when grown in different localities*

Variety	Source of Crop	Reaction of soil	Percentage of protein	Percentage of oil	Iodine number of oil
Black Eyebrow	Ewing	M. L. P. K.	45.14	18.44	121.2
	Effingham	Not known	44.30	18.64	123.6
	Spring Valley	Lime	43.41	18.77	123.3
	Gibson City	Slightly acid	41.68	19.83	126.5
	Freeburg	Acid	37.90	21.58	121.5
Manchu	Spring Valley	Lime	43.53	18.24	133.8
	Gibson City	Slightly acid	41.62	19.81	128.8
	Woodford Co.	Unknown	34.77	21.62	132.4
	Decatur	Slightly acid	32.81	23.21	131.5
Midwest	Spring Valley	Lime	44.74	15.54	131.8
	Effingham	Unknown	43.77	17.18	130.0
	Woodford Co.	Unknown	38.30	18.02	134.7
	Freeburg	Acid	37.25	18.60	127.3
	Decatur	Slightly Acid	35.13	18.79	131.3
Wilson Five	Ewing	M. L. P. K.	44.03	16.31	135.6
	Effingham	Unknown	40.35	16.68	135.3
	Woodford Co.	Unknown	36.78	17.48	139.0
	Decatur	Slightly acid	34.86	18.12	135.5
	Freeburg	Acid	33.52	19.26	136.1

It will be observed that, within each variety, remarkable differences existed in the composition, depending upon the locality in which the beans were grown. This is especially true of the protein content. It is interesting to note that those beans had a high protein and a low oil content which were grown on land that had been limed or that had been limed and otherwise fertilized. On the other hand, low protein and high oil content were associated with an acid soil. Herein apparently lies the cause of the wide variation within the varieties. It probably is not so much due to geographical position or climatic conditions, but is influenced chiefly by an abundance of plant food and by the reaction of the soil.

The beans grown upon the Sparta and the Odin soil fields afford an opportunity to study this problem further. The untreated soil of both these fields is acid and lacking in fertility. The Haberlandt variety of beans was grown upon each of these fields. In Table 5 is shown the percentage of protein found in the beans grown on plots 1 to 4 at Sparta and at Odin.

TABLE 5.—*Showing the gradual approach in protein content of the beans grown at Sparta and at Odin as the fertility requirements are met.*

Soil treatment	Sparta	Odin	Differences
None	34.79	41.52	6.73
R.	36.18	39.79	3.61
R. L.	43.51	45.28	1.77
R. L. P.	44.37	45.66	1.29
R. L. P. K.	43.27	43.34	.07

There was found to be a difference of 6.73 percent in the protein content of the beans grown on the untreated plots. The difference was in favor of those produced on the check plots at Odin. From these data, it might be inferred that the locality or geographical position had greatly influenced the composition of the beans. However, with the addition of crop residues to the soil, the difference in composition became less marked. Limestone added to the soil, in addition to the crop residues, reduced the difference in protein content to 1.77 percent. Where phosphorous was applied in addition to residues and limestone, the difference was only 1.29 percent, and with the further addition of potassium, the protein content became practically identical. From the data presented here, it would appear that the chief factors affecting the composition of soybeans grown in different localities are soil fertility and soil reaction.

DIFFERENCE IN COMPOSITION DUE TO VARIETY CHARACTERISTICS

It is generally acknowledged that there may be rather wide differences in the composition of varieties of soybeans. The four varieties, data for which are presented in Table 4, together with the two used in the study of the effect of soil treatment upon composition (See Table 1, Carthage, plot 4; Raleigh, plot 4; Sparta, plot 8; and Odin, plot 4) afford an opportunity to make observations on this phase of the subject.

W. J. Morse (4) gives the following data concerning the protein content of four of these varieties.

Black Eyebrow	40.8	percent
Haberlandt	38.5	"
Wilson Five	37.8	"
Manchu	37.2	"

It may be assumed from these figures that there is normally a difference of from three to four percent in the protein content of the Black Eyebrow and the Manchu varieties of soybeans.

In Table 6, there are assembled the data showing the highest percentage of protein found for each of the varieties studied, together with the soil treatment. These data were selected from Tables 1 and 4.

TABLE 6.—*Record of the high protein beans showing that in every case high protein content is associated with a soil supplied either with lime alone or with lime in conjunction with organic matter and other mineral fertilizing elements.*

Where grown	Variety	Soil treatment or reaction	Percentage of protein	Percentage of oil
Carthage	Manchu	M. L. P.	46.19	18.29
Ewing	Black Eyebrow	M. L. P. K.	45.75	18.97
Odin	Haberlandt	R. L. P.	45.66	17.77
Spring Valley	Manchu	Limed	44.99	17.94
Spring Valley	Midwest	Limed	44.74	15.54
Raleigh	Haberlandt	M. L. P.	44.42	19.26
Sparta	Haberlandt	R. L. P.	44.37	18.49
Ewing	Wilson Five	M. L. P. K.	44.03	16.31

Where the conditions were favorable for high protein production the varieties tended, in a rather remarkable degree, towards uniform protein content. Under these conditions, the Manchu grown at Carthage contained 0.44 percent more protein than did the Black Eyebrow grown at Ewing; while the Manchu grown at Spring Valley contained 0.76 percent less. The extreme variation in protein content between the varieties when grown under conditions favorable for large protein production ranged from 46.2 percent in the case of the Manchu grown at Carthage to 44.03 percent in the case of the Wilson Five grown at Ewing.

From the data presented in Tables 4 and 5, it is evident that there may be greater differences in the composition within the variety than exists normally between different varieties. Also, it would appear, at least in the case of the varieties studied, that where the beans are grown under conditions favorable for maximum protein production (conditions which are also favorable for high yield) there is a strong tendency for the different varieties to approach a uniform protein content.

Finally, it should be stated that within the variety, there is a fairly close correlation between the percentage of protein and of oil. In general, those beans having the highest percentage of protein contain the least oil and conversely, those containing the smallest percentage of protein have the greatest percentage of oil.

IODINE NUMBER OF SOYBEAN OIL

One of the important uses for soybean oil is as a substitute for linseed oil in the manufacture of paint and varnish. Its value for this purpose depends upon the amount of unsaturated acid contained. It follows that in a study of the factors affecting the oil content of soybeans, it becomes of interest to learn what effect, if any, such factors have upon the iodine number which is taken as an index of the degree of unsaturation.

The results of the determinations given in Table 1 will be considered first. The variety grown at Carthage was the Manchu. The average iodine number found for the different treatments was 131.8, and there was a difference between the maximum and miminum number of only 2.5 points. In this case, there was found no evidence that any consistent relation exists between soil treatment and iodine number. This same result was found in the study of oil from the different plots at Raleigh, Sparta, and Odin, where the Haberlandt variety of beans was grown.

It will be seen on examining the data given in Table 6, that there are wide differences in the average iodine number characteristic of the different varieties. The Black Eyebrow variety gave an average iodine number of 123.2 while for the Wilson Five, the number was 136.3, a difference of 13.1 points. Within the varieties there was found considerable variation but it was not sufficiently consistent to indicate that location or soil treatment was responsible.

SUMMARY

There appears to be some correlation between yield of beans and their composition. An increase in yield of beans on adjacent plots due to soil treatment was found frequently to be associated with an increase in protein content and a decrease in oil.

Applications of limestone and organic matter were found to increase the percentage of protein and decrease the percentage of oil in a marked degree.

Applications of rock phosphate in addition to limestone and organic matter still further increased the protein content and decreased the oil.

Potassium applied in addition to rock phosphate, limestone, and residues resulted in a decrease in the percentage of protein and an increase in that of oil.

The yield of oil in pounds per acre was increased by applications of organic matter. Limestone in addition to organic matter caused a

large increase in the production of oil, while phosphorus and potassium apparently had little effect upon the yield of oil per acre.

Wide variations may exist in the composition of the same variety of soybeans when grown in different localities. Such variations as were observed in this investigation were apparently not due to geographical position, or climatic condition, but may probably be attributed chiefly to differences in soil fertility and soil reaction.

There may be greater differences in composition within the variety than exists between most varieties.

The evidence obtained in this investigation would seem to indicate that soybeans tend toward a uniform protein content when the conditions are favorable for large protein production.

There is a fairly close correlation between the protein and the oil content of different lots of the same variety of soybeans. Conditions which produce an increase in the percentage of protein result in a decrease in the oil content and *vice versa.*

Varieties of soybeans may differ considerably in the iodine number of their oil.

Variations occur in the iodine number within the variety, but no consistent relation was found to exist between iodine number and location or soil treatment.

LITERATURE CITED

1. Feller, C. R. The effect of inoculation, fertilizer treatment, and certain minerals on the yield, composition, and nodule formation of soybeans. *In* Soil Sci. 6:81–129. 1918.
2. Garner, W. W., Allard, H. A., and Foubert, C. L. Oil content of seeds as affected by the nutrition of the plant. *In* Jour. Agr. Res. 3:227–249. 1914.
3. Lipman, J. G. and Blair, W. A. Factors influencing the protein content of soybeans. *In* Soil Sci. 1:171–178. 1916.
4. Morse, W. J. The soybean: Its culture and uses. U. S. Dept. Agr. Far. Bul. 973. 1918.
5. Piper, C. V. and Morse, W. J., The Soybean. p. 125–126. McGraw-Hill Book Co. 1923.

NATURAL CROSSINGS IN OATS AT AKRON, COLORADO[1]

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INTRODUCTION

The extent of natural crossing resulting when different crop varieties are grown on adjacent plats is of prime interest. It has long been recognized that when strains of corn, the sorghums, or rye are grown in close proximity, natural crossing usually takes place freely. Formerly it was believed that natural crossing rarely occurred among the so-called close-fertilized cereals, wheat, oats and barley. However, evidence to the contrary has accumulated, which indicates that this belief was not well founded. Numerous reports of the occurrence of natural crosses in varieties of close-fertilized cereals have been published and it is now generally recognized that some crossing may result when different strains of these cereals are grown close to each other.

It generally has been thought that climatic conditions, as well as certain physiological phenomena, influence the extent of natural crossing occurring in them, but apparently this belief is not based on experimental evidence. Few systematic experiments ever have been conducted with the idea of determining the extent of natural crossing in cereal crops, and, as far as is known to the writers, none has been conducted to determine the relative extent of crossing under different climatic conditions.

REVIEW OF LITERATURE

No published data have been available from experiments conducted systematically to determine the extent of natural crossing of oats in America. A review of the literature on the subject shows that the opinions of different authors have varied as to the extent of such crossing. Although it was formerly believed by most authors to be infrequent or of rare occurrence, occasional reports describing supposed natural crosses or field hybrids in oats have been published.

Rimpau (19)[3] recorded a natural cross between black and white oats in 1880 and observed that the progeny of the hybrid plant grown in 1881 contained white and black kernels in a series representing various shades of brown. This was the only known case of natural cross-

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[3]Reference by number is to "Literature Cited," p. 658.

ing which he had observed in several years' work with different oat varieties. He believed that spontaneous variations are as numerous in oats as in wheat, but not as readily observed. The same author (20) describes four natural crosses in oats, and states that he had observed five cases of natural crosses in fifteen to twenty-three oat varieties grown during the six years 1879-1884. This observation led him to believe that natural crossing in oats is more frequent than he had previously supposed.

McAlpine (15) speaks of natural crossing as being a "rare event in cereal life" and cites Rimpau's report on natural crossing in the oat.

Jamieson (11) of Scotland, believed that oats cross freely when planted side by side. In his experiments, he found that seeds from such crosses produced heavier plants than seeds from uncrossed plants.

Cannon (3) made a detailed morphological study of the flower and embryo of the wild oat, *Avena fatua* L. He observed that the pollen is generally shed before the stigmas have protruded from the spreading glumes.

Norton (14) found that in the wild oat, *Avena fatua*, and in many cultivated varieties, the flowers open wide, allowing the double stigma to project on each side and the anthers to fall down as far as the lengthened filaments will permit. In oats of this type, it is entirely possible that natural crossing takes place, but in many varieties the flowers do not open wide enough to allow the stigma to protrude at all and many flowers even keep the anthers inside the glumes. He believed that most persons who have worked on the problem have come to the conclusion that natural crossing in the oat is rare. To test the point a large number of flowers were emasculated by him and left uncovered under conditions favorable for crossing, but no seed was obtained, while at the same time artificial crosses were about 75 per cent successful, on an average.

Hunt (9) stated that the indications are that oats are nearly always self-fertilized and that no American cross-bred variety of oats has yet been widely distributed.

Hays (8) stated before the Horticultural Society of New York that "it seems quite practicable to assume that the oat is almost entirely self-pollinated."

Peacock (16) stated that owing to the artificial cross-fertilizing of many of the cultivated oat varieties grown in New South Wales many have been produced which possess intermediate characteristics.

Livermore (12) studied natural cross-fertilization in oats, by sowing unlike varieties in adjacent nursery rows and observing the off types which occurred in the following season and which might be at-

tributed to crossing. The distinguishing characters used were lemma color and the hulled or hull-less condition of the kernels. His results indicate quite clearly that natural crossing had taken place in the case of the hull-less oats exposed to the hulled oats. In the case of lemma color, some of the original seed was found to be mixed, and the results therefore could not be considered as entirely reliable. The evidence was such as to indicate that natural crossing is possible and does occur in oats, and is a factor with which the breeder must deal.

Pope (17) describes the mode of pollination in oats and other crop plants and quotes the opinions of several other workers on the amount of natural crossing which occurs in oats. He states that it appears that although the possibility of crossing in oats is greater than in either wheat or barley, it very seldom occurs.

Babcock and Clausen (2) classify plants with respect to their mode of reproduction. They include oats in the group described as: "Plants normally self-fertilized; flowers hermaphrodite, but the floral mechanism such as to preclude cross-pollination." These authors quote Pearl and Surface as observing no cases of natural crossing in their extensive investigations in oat breeding.

Love and Craig (13) state that no natural oat hybrid has yet been found in the course of their extensive varietal and breeding experiments.

Fraser (6) states that no clear case of natural crossing in oats has ever been observed at the Cornell University Experiment Station.

Heribert-Nilsson (10) found that selection was effective within a pedigree variety, indicating that cross fertilization is not excluded in oats.

Hayes and Garber (7) state that Pridham observed a natural cross between *Avena sterilis* and *A. nuda* in 1916. These authors consider that numerous statements by breeders as to self-fertilization show that natural crossing occurs much less frequently in oats than in wheat.

Crepin (4) described what he believed to be a natural hybrid between *Avena fatua* and *A. sativa*, which apparently is similar to the so-called false wild types found in cultivated oat varieties of the United States.

Akerman (1) observed that in sowings of cultivated oats individuals are sometimes found that differ in many points from the common type and bear a certain resemblance to *Avena fatua*. These aberrant forms appear not only in the pure lines, but also in the mixed populations. At first he assumed that they were due to a natural cross between cultivated and wild oats, but this appeared not to be the case,

since *A. fatua* is not found in the district of Svalöf where Nilsson-Ehle has made a prolonged study of these anomalous forms and in true crosses segregation is very complicated, a large number of characters being involved. Excluding the hybrid origin, the fatuoid form must be regarded as a mutation.

These statements from different investigators indicate that their opinions vary as to the amount of natural crossing which may occur in oats. Jamieson (11) who believed that natural crossing in oats occurs very commonly, is contrasted with McAlpine (15), Norton (14), Hays (8), Hunt (9), Pope (17), Love and Craig (13), Fraser (6), and Hayes and Garber (7), who believe that natural crossing seldom occurs.

The writers do not believe that oats cross in nature to the extent that Jamieson has indicated; but the results of the experiments herein reported indicate that field crosses do occur in oats, and the extent of such crossing should be given consideration in conducting oat experiments. The senior author has observed several instances of apparent natural crossing in oats at Ames, Iowa, and Aberdeen, Idaho. Most of these field hybrids were between hulled and hull-less varieties, thus indicating that the loose palea and glume of the naked oat favors rather than hinders cross fertilization.

EXPERIMENTAL MATERIAL

During the past few years numerous variant oat forms have been observed by the junior author in the experimental seedings of oats at the Akron (Colo.) Field Station of the United States Department of Agriculture. The occurrence of so many aberrant forms in any one locality in so short a period is unusual. The cause of these variations is not definitely known, but their breeding behavior usually has indicated that they apparently were not of hybrid origin. Natural crosses in oats generally have been believed to be rare, but due to the occurrence of these numerous variant forms, it was decided by the writers to conduct an experiment to obtain information on the extent of such crossing at Akron.

A total of eight oat varieties, four black and four white, were chosen for use in this experiment. In seeding, a black variety and a white variety were paired. The four pairs were as follows:

	Black.			White.
C. I. No.	549[4]	Black American, (Akron Sel. 02 BA)	C. I. No. 459,	Kherson (Akron Sel. 8-1-18)
"	1092,	Early Joanette,	"	1623, Early Champion
"	836	(Unnamed),	"	1717, Pringle Progress
"	1760,	Monarch,	"	1585, Iowar

[4]Cereal Investigations accession number.

HISTORY AND DESCRIPTION OF VARIETIES

All of the varieties used in this experiment are classified as belonging to *Avena sativa*. Several of them are of commercial importance, while others are obsolete or of no promise economically. However, each variety was uniform in plant characters and apparently had been breeding true. The members of each pair were chosen primarily because of their similarity in time of heading and ripening, as it was realized that if natural crossing was to take place the varieties should flower simultaneously.

Black American, C. I. No. 549 (Akron Sel. 02 BA). The Black American variety was received by the Office of Cereal Investigations from the substation at Nephi, Utah, in the spring of 1908. It was first grown in the plats at the Akron Field Station in 1913. Several similar strains of black oats have been grown in classification nurseries by the Office of Cereal Investigations under the name of Black American. Some have been identified as representing either the Monarch or North Finnish varieties, while others (including C. I. No. 549) were similar to or identical with Joanette. However, the Akron selection of Black American which was used in this experiment, under the conditions at Akron, Colo., produces rather large, spreading panicles and matures earlier than the Joanette variety. The kernels usually are black or dark brown, and frequently are quite glaucous. Some of the spikelets are awned. This variety is of no importance economically.

Kherson, C. I. No. 459. (Akron sel. 8-1-18). The history of the Kherson variety has been published by Warburton and Stanton (21). The selection from Kherson used in this experiment was made at the Akron Field Station in 1917 by the junior author. The plants of this particular selection are of a lighter shade of green, a little taller, and a trifle later in maturing than the parent variety. The kernels are very pale yellow or almost white. The selection was first grown in the nursery at Akron, Colo., in the summer of 1918. The Kherson, Sixty-Day, and their various selections, such as Albion (Iowa No. 103), Richland (Iowa No. 105), Iowar, Nebraska No. 21, States Pride, Gopher, etc., constitute one of the most important groups of varieties of oats grown in the United States.

Iowar, C. I. No. 1585. This strain of Kherson was received from the Adams Seed Co., Decorah, Iowa, on March 30, 1920, under the name of Albion (Iowa No. 103). It was grown in the classification nursery of 1920, and was identified as Iowar, as it was a little later in maturity and a little taller than Albion (Iowa No. 103), C. I. No. 729.

The Albion and Iowar strains differ primarily from the original Kherson in having white kernels.

Early Champion, C. I. No. 1623. This strain of Early Champion was received by the Office of Cereal Investigations from the Illinois Agricultural Experiment Station, in 1913. The origin of the Early Champion variety is uncertain. It apparently was introduced to the seed trade by the Iowa Seed Co., Des Moines, Iowa, in 1898. It is an early, white-kerneled variety, similar to Albion. It is differentiated from that variety primarily by its slightly later maturity, taller culm, shorter and more erect panicle, and slightly plumper kernel. This variety has been very susceptible to smut, and frequently can be identified by the great prevalence of smut in it. The Early Champion variety originally was grown to a considerable extent in Iowa and adjoining States but is of less importance than formerly.

Early Joanette, C. I. No. 1092. This strain of black oats was received by the Office of Cereal Investigations from W. H. Small, Inc., Evansville, Ind., February 20, 1920. It was received under the name of Joanette, but is much earlier than that variety. This variety is apparently similar to or identical with the variety described by Marquand, of the Welsh Plant Breeding Station, as Early Joanette. Its origin has not been determined. However, it may have originated from a natural hybrid between Joanette and Kherson, or a similar early yellow, or white variety. The straw is short to midtall and rather slender. The panicle is smaller than that of Joanette, and the kernels are similar. As far as can be determined, this variety is of little or no economic importance in the United States.

Monarch, C. I. No. 1760. This variety was received by the Office of Cereal Investigations in 1913 from the Delaware Agricultural Experiment Station. The origin of Monarch is undetermined. It is an early black-kerneled variety with midtall, fairly stiff culms. The outstanding characteristic is the dense bloom which occurs on the mature lemmas. This particular strain is identical with the Monarch of Etheridge (5).

Pringle Progress, C. I. No. 1717. This variety was developed by the late C. G. Pringle of Vermont about 40 years ago, from a cross between a strain of common oats known as Excelsior and the Chinese Hull-less. It was given an accession number by the Office of Cereal Investigations in February, 1920, but had been grown previously by that Office. In maturity it is early to midseason, and produces a rather short stiff straw. In panicle and kernel characters it is similar to the Green Russian variety. This variety apparently has become practically obsolete.

C. I. No. 836.[5] An unnamed black oat presented by Vilmorin-Andrieux & Company of Paris, France. It was received November 30, 1917. Under conditions in this country this oat has been rather short in the straw, and is similar to Joanette, except that the kernels are somewhat larger. Owing to the undesirable color of kernel this oat has not been commercialized in this country.

EXPERIMENTAL DATA

METHODS IN 1922

In starting these experiments, twelve panicles were selected from each of the eight varieties used. These panicles were typical of the varieties represented. The pairings of the varieties was made with reference to their respective dates of heading, as determined in previous experiments. In all cases a black was paired with a white variety heading at approximately the same time. The kernels from the twelve panicles of these paired varieties were sown in alternate adjacent rows, first a black, then a white, until the twenty-four rows of each pair were sown.

Numerous investigators have shown conclusively that in crosses between black (dark-colored) and yellow, or white (light-colored), oat varieties, the black or dark color is in all cases dominant in the F_1 generation. For this reason, varieties of black and of white oats were used in making these studies of natural crossing. The arrangement of the varieties in the rows was believed to be such as would result in the maximum opportunity for crossing in an experiment of this nature.

A total of ninety-six rows was sown. The seed was sown April 22, and the plants emerged May 5. Fair stands were obtained in all rows. Climatic conditions at Akron in 1922 were unfavorable, and the oat plants suffered from lack of moisture.

At harvest time the plants for each row were pulled, tied together in bundles, and stored. As time permitted, the plants in each bundle were examined closely for variant forms or possible hybrids, but no abnormal individuals were observed among the progeny plants from any of the selections of the eight varieties.

[5]*Avena sativa* L. Poaceae.

"Hybride noir très nâtive [very early black hybrid]. This variety was obtained about 10 years ago at the experimental farm at Verrieres by crossing the Australia and Joanette varieties. It has been carefully selected and has proved itself to be a well-fixed variety which is vigorous, tillers well, and attains a height of 4 to 5 feet, according to cultural conditions. The panicle is well filled and perfectly continuous, and the spikelets contain two and often three beautiful, black, full, faintly awned grains.

"In our comparative studies this variety has constantly ripened 8 or 10 days in advance of the earliest, established varieties, giving a greater yield. Sown the first of March it heads early in June, and ripens about the 20th of July. In brief, it is highly profitable, uniting the best qualities—extreme earliness, abundant production, and resistance to rust and to shattering." (Vilmorin-Andrieux & Co.)

As previously noted, results obtained from numerous hybridization experiments in oats show that so far as determined black is dominant to all other kernel colors. The F_1 generation of the white × black oats would be very nearly like the parent blacks phenotypically with regard to kernel color. As a result, even though heterozygous individuals might have existed in the progeny of the black selections, their presence could not have been detected in the next generation. However, the progenies from the rows of the black selections were examined equally as carefully as those from the white selections. This was done to determine conclusively that they were genotypically, as well as phenotypically, black. After examining these plants they were discarded.

METHODS IN 1923

Only seed from the selections of the white varieties grown in head rows in 1922 was used in conducting the 1923 experiments. After the plants had been examined for possible variants, the grain from each row was threshed separately. The seed from each head row of the white varieties grown in 1922, was used for sowing a rod row in 1923. The rate of seeding varied with the amount of seed available, some of the head rows producing more grain than others. Usually the entire yield of the head row was sown in the rod rows.

The seed was sown on April 24 on land fallowed the previous season. Moisture conditions at seeding time were favorable and the plants emerged on May 1. Fair stands resulted in most of the forty-eight rod rows. Weather conditions during the growing season of 1923 were much more favorable at Akron than in 1922 and as a result the plants made a fair growth. Grasshoppers were numerous at Akron in 1923, and damaged the plants in these rows. The number of plants completely destroyed by them was not large enough to be significant but an appreciable percentage of the kernels was lost from practically all plants.

At harvest the plants from each row were pulled, tied together in a bundle, and stored. They later were examined closely for variant, or supposed hybrid, individuals. The numbers and percentages of black and white plants in each row and the totals are shown in Table 1.

In all, forty-one variants or black-kerneled plants were found in the F_1. The seed from these was sent to the Arlington Experiment Farm for sowing in pots in the greenhouse. This seed was sown about October 20, 1923. Usually, three kernels were sown per pot. Each pot was labeled to show the record number of each variant or black-kerneled plant from which the seed was taken and the rod row in which it appeared.

Table 1.—*Showing numbers and percentages of black-kerneled and white-kerneled F_1 plants, in each of twelve rod rows from each of four varieties.*[a]

C. I. No.	Variety	Rod row number 1923	Plants produced: Number: White-kerneled	Black-kerneled	Total	Percentage of black-kerneled
459	Kherson (Akron Sel. 8-1-18)	1	231	0	231	0.00
		2	239	0	239	.00
		3	228	0	228	.00
		4	218	0	218	.00
		5	97	0	97	.00
		6	171	0	171	.00
		7	177	0	177	.00
		8	168	0	168	.00
		9	156	2	158	1.27
		10	253	1	254	.39
		11	125	0	125	.00
		12	222	1	223	.45
	Summary		2,285	4	2,289	.17
1623	Early Champion	1	229	0	229	.00
		2	341	2	343	.58
		3	372	0	372	.00
		4	286	1	287	.35
		5	394	6	400	1.50
		6	459	2	461	.43
		7	261	0	261	.00
		8	462	2	464	.43
		9	278	0	278	.00
		10	268	0	268	.00
		11	335	0	335	.00
		12	260	0	260	.00
	Summary		3,945	13	3,958	.33
1717	Pringle Progress	1	169	0	169	.00
		2	191	0	191	.00
		3	127	0	127	.00
		4	169	0	169	.00
		5	126	0	126	.00
		6	330	0	330	.00
		7	145	0	145	.00
		8	175	0	175	.00
		9	168	0	168	.00
		10	166	1	167	.60
		11	149	0	149	.00
		12	187	1	188	.53
	Summary		2,102	2	2,104	.10
1585	Iowar	1	179	8	187	4.28
		2	89	0	89	.00
		3	91	2	93	2.15
		4	190	1	191	.52
		5	135	1	136	.74
		6	282	1	283	.35
		7	206	4	210	1.90
		8	227	2	229	.87
		9	231	1	232	.43
		10	226	0	226	.00
		11	234	0	234	.00
		12	164	2	166	1.20
	Summary		2,254	22	2,276	.97
	Summary all varieties		10,586	41	10,627	.39

[a]Including the plants which failed to segregate in F_2.

Conditions in the greenhouse during the winter of 1923-1924 were very favorable and the plants made an excellent growth. By means of electric lights installed through the center of the greenhouse above the oat plants, their maturity was considerably hastened. By late March, practically all the plants were sufficiently ripe for determining the color of the kernels.

Several unfavorable conditions influenced these experiments, but the results were generally satisfactory. Mice completely destroyed a number of the plants and injured others by gnawing off the ripened panicles. Several additional plants were discarded, as they were completely smutted. Fortunately progeny plants of all the forty-one variants were grown to maturity, thus permitting observation of their breeding behavior. As shown in Table 2, only thirty-eight of these produced segregating progeny.

Table 2.—*Showing number of rows of white-kerneled oats which segregated in F_1 and number of black-kerneled F_1 plants produced, and number segregating in F_2.*

C. I. No.	Variety	Number of: Parent rows in 1922	Segregating rows in 1923	Black-kerneled plants: Produced in 19 rows in 1923	Black-kerneled plants: Producing segregating progenies in 1924
459	Kherson (Akron sel. 8-1-18)	12	3	4	4
1623	Early Champion	12	5	13	12
1717	Pringle Progress	12	2	2	1
1585	Iowar	12	9	22	21
	Totals—	48	19	41	38

Of the forty-one parental individuals from which progenies were available for study, at least thirty-eight proved to be F_1 hybrids, as they produced progeny which segregated for kernel color. The other three black-kerneled variants produced nineteen plants which showed no segregation. Of these three plants, two produced but three plants each, while the third produced thirteen progeny plants. The failure of the progeny of these three variants to show segregation may have been due to any of the following causes: (1) mechanical mixture; (2) insufficient number of progenies for permitting free operation of the law of selective assortment; or (3) to presence of complementary factors in white parents which when naturally crossed produced black progeny.

A progeny of 893 plants was produced from the forty-one black-kerneled parent plants. However, due to the ravages of mice and the damage resulting from smut, data could be recorded only on 796 of the F_2 plants.

From the data shown in Table 3, it will be seen that the segregation

Table 3.—*Summary of data showing the genetic behavior in the F_2 of 38 natural crosses of 1923 when grown in the greenhouse at Arlington Experiment Farm in the winter of 1923–1924.*

C. I. No.	Variety	No. of F_1 segregating plants	F_2 plants: No. producing Black or brown kernels	No. producing White kernels	Percentage producing Black or brown kernels	Percentage producing White kernels
459	Kherson (Akron sel.8-1-18)	4	64	28	69.57	30.43
1623	Early Champion	12	122	50	72.09	27.91
1717	Pringle Progress	1	42	15	73.68	26.32
1585	Iowar	21	335	137	70.97	29.03
	Totals—	38	563	230	71.11	28.89
	Expected in ratio of 1:2:1		597	199	75.00	25.00
	Deviation from expected		—31	+31	—3.89	+3.89

of these progeny plants into the classes of black or brown, and white, approached the Mendelian ratio of three colored to one white, as usually results in the F_2 generation in controlled crosses of white × black oat varieties. Of the population of 796 surviving plants, 566 were colored and 230 were white.

DISCUSSION OF RESULTS

The results obtained from this experiment prove that natural crossing does occur in oats at Akron, Colorado. The data obtained show that in 1922, black and white oats grown in adjacent head rows crossed naturally to the extent of at least 0.36 percent of the progeny of the white oats in the succeeding generation. The fact that the progenies of thirty-eight of the forty-one black-kerneled varieties exhibited definite genetic segregation shows conclusively their hybrid origin. The possibility that the three doubtful variants were hybrids increases the probable amount of natural crossing to 0.39 per cent.

It seems reasonable to assume that the extent of natural crossing between the plants within the same row (that is, white with white and black with black) was equal to that actually observed in the first generation between black and white plants. If this be assumed, then theoretically the amount of crossing in the experiment conducted at the Akron Field Station in 1922 was twice that shown by the data obtained. On this assumption, the average crossing for all varieties was 0.72 percent, and possibly 0.78 percent. The average extent of crossing in the most susceptible variety was possibly 1.94 percent; while that in the head row which exhibited the most crossing was possibly 8.65 percent.

If, however, there be excluded from all consideration the plants which produced progeny which did not segregate, there were in row

8 of Early Champion a total of 463 plants, one of which was a proved hybrid. This is 0.22 percent of natural crossing, which multiplied by two would be 0.44 percent. The variety contained 3,957 plants, of which twelve, or 0.30 percent, were natural crosses, which when multiplied by two indicates 0.60 percent of natural crosses.

Only one of the aberrant plants found in Pringle Progress proved to be a natural cross. The progeny of the variant found in row 10 of this variety failed to segregate in the second generation. As a result, the amount of proved crossing in the variety is reduced. Excluding this plant, there were 2,103 plants, of which one proved to be a natural cross. The percentage of natural crosses, therefore, was 0.05 percent, which when multiplied by 2 is 0.10 percent.

Only one of the two aberrant plants found in selection row eight of Iowar, produced progeny which segregated. As in the other two cases, the number of plants is reduced from 229 to 228, and that of variants from two to one. The percentage of natural crosses becomes as follows: normal 99.56, 0.44 percent, which when multiplied by two gives 0.88 percent as the possible extent of crossing. The totals for the variety are changed to 2,275 plants, 21 of which are proved hybrids. This gives 0.92 percent of crossing, which when multiplied by two would indicate 1.84 percent as the possible natural crossing. These changes also change the totals for the entire experiment. The total number of plants considered is reduced by three, or from 10,627 to 10,624, while the number of aberrants is reduced from forty-one to thirty-eight. As a result, the percentage of proved natural crossing is 0.36, instead of 0.39 percent. This multiplied by two gives a percentage of 0.72 instead of 0.78.

These data indicate that the extent of natural crossing varied in the different varieties and also in the different head selections within varieties. This might indicate that crossing in some oat varieties may occur more readily than in others. The greatest percentage of natural crosses was observed in Iowar (C. I. No. 1585) in which an average of nearly one percent of crosses was found. In one selection row of this variety, 4.32 percent of the progeny were natural crosses. The prevalence and extent of the natural crossing in this variety is more fully realized when it is noted that three-fourths of the rod rows of the variety contained one or more natural crosses. Crosses were found in at least one-sixth of the rows of all varieties. The least crossing was observed in Pringle Progress (C. I. No. 1717) in which but 0.05 percent of known crosses was found. If natural crossing in oats

is as frequent as these figures indicate, it is not surprising that marked variability exists in many oat varieties.

These data clearly indicate the necessity for careful study of the breeding behavior of all material to be used in making crosses for investigating the genetics of oats. They also may assist in explaining the genetic data not in conformity to usual genetic ratios that have been obtained from hybridization experiments in oats. Further, it is possible that natural crossing may furnish an explanation for the occurrence of some of the widely aberrant forms observed in oat varieties.

The need for more consideration of the question of natural crossing of oats when planning plat and nursery experiments is indicated clearly by the results obtained in these experiments.

SUMMARY

In the present investigation to determine the extent of natural crossing in oats at Akron (Colo.) Field Station, it was found that:

Without doubt natural crosses do occur in oats;

The extent of such crossing varied with the different varieties;

The amount of natural crossing was greater in some selections than in others from the same variety.

It would appear that in oats natural crossing may account for some of the variability observed in supposedly pure-line varieties, as well as for the frequent occurrence of widely aberrant forms in certain varieties.

It is desirable that a study should be made of the breeding behavior of all oat strains to be used in genetic investigations, and that the inheritance of certain characters be determined by growing the strains under careful observation for several generations previous to making crosses.

The need for formulating better methods in plat and nursery technique in conducting experiments with oats is apparent if the factor of natural crossing is to be eliminated.

LITERATURE CITED

1. AKERMAN, A. Undersökningar rörande flyghavrelika mutationer i vanlig odlad havre. *In* Sveriges Utsädesför. Tidskr. 31: 266–268. 1921.
2. BABCOCK, E. B. and CLAUSEN, R. E. Genetics in Relation to Agriculture. McGraw-Hill Book Co., N. Y. 1918.
3. CANNON, W. A. A morphological study of the flower and embryo of the wild oat, *Avena fatua* L. *In* Proc. of Calif. Acad. Sci., 3rd ser. Bot. 1:329–355. 1900.
4. CREPIN, Ch. Sur un hybride naturel entre *Avena fatua* et *Avena sativa* à glumelles jaunes. *In* Ann. École Nat. Agr. Grignon 7: 143–154. 1920–21.

5. ETHERIDGE, W. C. A classification of the varieties of cultivated oats. N.Y. (Cornell) Agr. Exp. Sta. Mem. 10. 77-172. 1916.
6. FRASER, A. C. The inheritance of the weak awn in certain *Avena* crosses and its relation to other characters of the oat grain. N. Y. (Cornell) Agr. Exp. Sta. Mem. 23:635–676. 1919.
7. HAYES, H. K., and GARBER, R. J. Breeding Crop Plants. McGraw-Hill Book Co., N. Y. 1921.
8. HAYS, WILLET M. *In* Proc. Internat. Conf. Plant Breed. and Hybrid. 1902:109. (Hort. Soc. N. Y. Mem., v. 1.)
9. HUNT, THOMAS F. The Cereals in America. Orange Judd Co., N. Y. 1904.
10. HERIBERT-NILSSON, H. N., Ett. försök med urval inom pedigreesorter av havre .[An experiment with selection among pedigree-varieties of oats.] 4 p. W. Weibulls Illustrerade Arsbok (Landskrona) 15 (1920.) 1919. (Abs in Bot. Abs. 5:52. 1920.)
11. JAMIESON, T. Natural cross fertilization of oats and change of seed. *In* Proc. Agr. Research Assoc. [Scotland] 1897:31–50; 1898:7–31; 1899:6–19. 1897–99.
12. LIVERMORE, K. C. Natural cross fertilization in oats. Unpublished thesis, Cornell University. 1912.
13. LOVE, H. H., and CRAIG, W. T. The relation between color and other characters in certain *Avena* crosses. *In* Amer. Nat. 52:369–383. 1918.
14. NORTON, J. B. Improvement of oats by breeding. *In* Proc. Internat. Conf. Plant Breed. and Hybrid. 1902:103–109. (Hort Soc. N. Y. Mem., v. 1.)
15. MCALPINE, A. N. Raising new breeds of cereals. *In* Trans. Highland and Agr. Soc. Scot. (ser. v.) 6:133–170. 1894.
16. PEACOCK, R. W. Oats. *In* Agr. Gaz. N. S. Wales 15: 765–772. 1904.
17. POPE, M. N. The mode of pollination in some farm crops. *In* Jour. Amer. Soc. Agron. 8:209–227. 1916.
18. PRIDHAM, J. T. Oat-breeding experiments. *In* Agr. Gaz. N. S. Wales 27: 457–461. 1916.
19. RIMPAU, W. Züchtung auf dem Gebiete der landwirtschaftlichen Kulturpflanzen. *In* Mentzel und v. Lengerke's Landw. Kalender, 2:33–92. 1883.
20. ———. Kreuzungsprodukte landwirtschaftliche Kulturpflanzen. *In* Landw. Jahrb. 20:335–371. 1891.
21. WARBURTON, C. W., and STANTON, T. R. Experiments with Kherson and Sixty-Day oats. U. S. Dept. Agr. Bul. 823. 72 p. 1920.

FIELD CROP RESPONSE TO THE INGREDIENTS OF POTASSIUM SALTS[1]

Burt L. Hartwell, S. C. Damon and F. K. Crandall[2]

Under certain conditions carriers of potassium, as well as of the other two fertilizer elements, may have marked crop effects other than those exerted by the fertilizer elements themselves serving directly as nutrients.

It was the purpose in this experiment to use magnesium-potassium sulfate, muriate of potash, sulfate of potash and kainit under such conditions that not only the potassium but also the other ingredients should have an opportunity eventually to exert on crop plants any effect of which they may be capable. Consequently not only potassium, but sodium, magnesium, sulfur and chlorin were reduced to the smallest practicable proportions in the basal applications common to all the plats.

Two-fifteenths acre plats (Nos. 114-118) of the permanent experimental area known as the station plain were selected for this purpose in 1911. They had not all been used exactly alike in previous years, but the new treatments were so arranged that it was believed that a satisfactory comparison could be made of the four potassium salts.

The soil is Miami silt loam which not only contained considerable available potassium but had received fairly liberal amounts of ordinary fertilizer chemicals, in consequence of which all of the elements (except probably magnesium) to be subsequently avoided in the basal applications had been applied. For example, in 1909 and 1910 the fertilizer contained nitrate of soda, acid phosphate, muriate and sulfate of potash, and even in 1911, 1912 and 1914, acid phosphate with its sulfur content was unfortunately applied.

One question of interest, therefore, was concerning the time when, if ever, there would be a depression in growth on the check, or no-potassium plat following the use therein of the basal applications of fertilizer chemicals in which the ingredients of the potash salts were at most no more than inconspicuous constituents.

No farm manure has been used in the experiment. The fertilizer applications, beginning with 1913, are stated in Table 1. In 1911 and 1912 combined, the basal fertilizer contained, besides other materials, 561 pounds of nitrate of soda and 1326 pounds of acid phosphate per

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[1]Contribution 310 of the Rhode Island Agricultural Experiment Station, Kingston, R. I. Received for publication July 28, 1924.

[2]Director and Agronomist, and Assistant Agronomists, respectively.

acre. By mistake 587 pounds of acid phosphate were also added in 1914. These materials of course supplied sodium and sulfur, but the other materials used throughout the experiment as carriers of nitrogen and phosphorus are not carriers of the ingredients of the potassium salts.

Table 1.—*Pounds of fertilizer ingredients applied per acre.*

Year	Nitrogen in				Phosphoric acid in				Potash in	
	Cyanamid	Calcium nitrate	Dried blood	Tankage	Tankage	Thomas slag	Double superphosphate	Precipitated phosphate	The various salts to plats 114, 115, 117, 118.	Sulfate to plat 119.
1911		45[a]		35	60		40[b]		139	
1912		40[a]	40				180[b]		150	
1913	15			25	16	85			50	100
1914		50					100[b]		35	105
1915	30			50	46	74			25	75
1916	40			50	46	50	104		50	100[c]
1917	24						100			75
1918	20		25				100			50
1919	25		25				100			50
1920	20			50	72		78		50	150
1921	30						100		50	150
1922	15	25		45	57		68	75	50	200
1923	18	35		30	32		118	51	50	150

[a]Added in nitrate of soda.
[b]Added in acid phosphate.
[c]Added in muriate.

In 1911 and 1912, the four salts were compared on an equal basis of 139 and 150 pounds respectively of potash per acre, which was doubtless more than was needed. As may be seen in Table 1, this was much reduced subsequently. In fact, potassium salts were omitted in 1917, 1918 and 1919 in order to create a deficiency of potassium, but were subsequently compared each year on a suboptimum basis of 50 pounds of potash. Plat 119, however, was included with an extra amount of potassium in order to show the yields when there was sufficient potassium.

None of the applications to these plats during their early history prior to this experiment was a recognized carrier of magnesium; but in 1911, 4 tons per acre of marl from Barton, Vermont, were used, in which the magnesium was not determined. There is no record of any subsequent application of lime, except in 1916, when one ton of hydrated lime per acre was applied. It is regrettable that the composition of this lime also cannot be stated. It is possible that it contained magnesium.

A discussion of the crop results may now be followed by reference to Table 2. Until 1918, there was apparently no deficiency of potassium salt even in the check plat which had received no potassium since 1910; and not until 1919, after omitting even the standard application of potassium salts for three years, was there on the

Table 2.—*Acre yields with the different potash salts when used with basal mixtures usually containing but small amounts, at most, of any of the ingredients of these salts.*

Year	Crops	Plat numbers and treatments 114 Kainit	115 Muriate of potash	116 No potassium	117 Sulfate of potash	118 Magnesium potassium sulfate	119 Sulfate of potash (extra amt.)
1911	Mangels, tons	33.8	27.8	27.8	23.7	22.8	——
	Carrots, tons	25.0	22.7	23.2	22.4	21.3	——
	Turnips, Swedish, tons	24.4	25.6	26.1	26.3	24.8	——
1912	Onions, bushels	530	554	478	435	525	——
1913	Oat hay, tons	2.36	2.96	2.89	2.63	2.21	3.00
1914	Grass and clover hay, tons	3.00	2.22	1.92	2.25	2.18	2.17
1915	Corn, ears, bushels	67	75	76	72	65	64
	stover, tons	4.54	4.24	3.93	4.03	3.71	3.82
1916	Potatoes, bushels[a]	89	98	108	134	123	123
1917	Wheat, grain, bushels	14	17	15	13	13	13
	straw, tons	1.19	1.28	1.64	1.18	1.09	1.07
1918	Grass and clover hay, tons[b]	2.59	2.87	2.06	3.43	2.14	3.28
1919	Orchard grass and alfalfa hay, tons	2.62	2.41	1.91	2.40	1.69	2.93
1920	Potatoes, bushels	137	163	56	125	127	271
1921	Sweet clover hay, tons	3.79	3.15	1.50	2.74	2.51	3.60
	Red clover hay, 2nd crop, tons	.94	.90	.38	.94	.83	1.91
1922 (Planted cross-wise the plats in duplicate)	Carrots, bushels	640	539	445	501	558	611
	Corn, ears, bushels	67	55	7	52	36	68
	stover, tons	2.00	1.58	.59	1.62	1.30	2.08
	Mangels, tons	32.2	19.3	6.8	19.3	12.1	29.9
	Oats, dough stage, tons	8.26	7.90	7.44	7.35	6.72	9.35
	Onions, bushels	129	86	20	89	132	335
	Potatoes, bushels	166	124	47	106	134	179
1923 (Planted length-wise the plats.)	Carrots, bushels	1019	951	654	796	850	977
	Corn, ears, bushels	54	50	17	56	46	51
	stover, tons	2.04	1.88	.83	1.82	1.73	2.34
	Mangels, tons	36.2	21.2	12.6	20.1	21.9	32.9
	Oats, tons	8.63	8.63	7.24	8.25	6.38	8.63
	Onions, bushels	212	318	129	275	270	415
	Potatoes, bushels	174	158	67	180	128	288

[a]Potato crop practically ruined by the extreme rainfall of 11.75 inches during July. Those sprayed three times with Bordeaux mixture produced only 73 per cent as great a yield of large potatoes as those sprayed nine times. Ounce pieces planted 9 in. apart in the drill produced 78 per cent as much as those planted 12 in. apart.

[b]It was estimated that the check plat had 50 per cent clover and the other plats 80 per cent.

plat to which an extra amount of potassium was added each year, a distinct increase in the yield of orchard grass and alfalfa then grown. Prior to that year, therefore, even the potassium in the salts had not had an opportunity to exert its full effect. Comparisons of yields before 1919 are consequently of little value and are excluded from the discussion of the comparative effect of the potassium salts.

First, attention should be called to the fact that in 1922 and 1923, when six crops were grown on each plat, the area occupied by each was insufficient to warrant close comparisons. Nevertheless, of the four plats to which were applied 50 pounds of potash, the one to which was added magnesium-potassium sulfate yielded the least and the kainit plat, the most. The yields of the sulfate and muriate plats were intermediate.

If the average percentage increase with magnesium-potassium sulfate over the no-potassium plat in case of the different crops grown during the last five years be considered as 100, the increase with sulfate was 109, with muriate 113, and with kainit 135. No claim is made at this time that the difference between the muriate and sulfate is significant. The superior yields with the kainit are most reasonably attributable to the well known usefulness of sodium when potassium is insufficient. A composite sample of the kainit used contained percentages equivalent to the following: potash, 13.6%; soda, 26.8%; magnesia, 3.3%; chlorin, 40.2%; and sulfuric oxid, 11.9%. This material has, therefore, about twice as much soda as potash; whereas the muriate, the only other of the potassium salts with an appreciable amount of sodium contains little more than a tenth as much soda as potash.

The magnesium content of the kainit was low, and since that in the magnesium-potassium sulfate was practically equivalent to the potassium, the proportion of magnesium was therefore greater than in any of the other salts. This element constitutes the principal difference in comparing with the high-grade sulfate applied to a contiguous plat. It would appear, therefore, that the magnesium in some way interfered with the most efficient use of the associated potassium.

Some attention in this connection has been given to the possibility, especially considering the low content of the alkalies, that the absorption of magnesium and calcium may not have been optimum. In the autumn of 1923, the carrots on the two plats now under discussion were sampled, and magnesium and calcium determinations made. There was practically no difference in the two samples, and the magnesium was less than the calcium, as is usual with carrots.

In Bulletin 189, of the Rhode Island Agriculture Experiment Station,

page 23, it is shown that in 1921 the acidity of the soil of these plats was represented by pH 6.1 to 6.5, and a calcium-oxid requirement of 1080 to 1800 pounds per two million pounds of soil (calcium acetate method). In July 1922, the surface soil of the no-potassium plat (No. 116) and of the plat receiving the most potassium (No. 119) had, respectively, 277 and 317 p. p. m. of active alumina soluble in 0.5 *N* acetic acid, and each a pH of 6.1. These determinations do not indicate a degree of acidity to which crops are sensitive, and the variations from plat to plat do not throw any light on the question at hand. The most acid plat was the no-potassium plat.

Determinations were made of the activity of the potassium in the surface soil, in order to secure indications especially as to whether the plat which receives magnesium-potassium sulfate had been depleted during the earlier years of the experiment, possibly through the influence of the associated magnesium sulfate. The following results in parts per million of dry soil were obtained:

		No-potassium plat (116)	Potassium sulfate plat (117)	Magnesium-potassium sulfate plat (118)
		p.p.m. K_2O	p.p.m. K_2O	p.p.m. K_2O
April 4, 1922	Sat. CO_2 water	8	11	10
	.04 *N* nitric acid	45	52	23
Oct. 9, 1923	"	97	182	75
April 3, 1924	"	68	138	111

One part of soil and five parts of solvent were used in the extraction.

The spring samples were taken before the fertilizer was applied, and the determinations made on the fresh soil. The autumn samples were stored over winter before the above determinations were made. It may be seen that in each case there was more active potassium in the soil to which potassium sulfate had been added than where the same amount of potassium sulfate was associated with magnesium sulfate.

Magnesium sulfate increases available potassium, but in the early years of the experiment when the latter was abundant this could serve no useful purpose and the near soluble potassium apparently became so depleted that in the later years the magnesium sulfate could make even less attack on the reserves than the other potassium salts.

SUMMARY

For ten years, the basal fertilizer common to all the plats has been composed of materials which are not carriers of potassium, sodium, magnesium, sulfur or chlorin.

These elements were added in one or more of the commercial potassium salts, kainit, muriate, sulfate and magnesium-potassium sulfate or double manure salt; and any effect on crop growth has been measured by comparison with the crops produced where only the basal fertilizer is used (no-potassium plat).

Even on this latter plat there was no apparent deficiency of potassium until 1918. The potassium salts were compared on the basis of an equal amount of potassium, which was recently suboptimum.

During the last five years, if the average percentage increase due to the magnesium-potassium sulfate is represented by 100, that with sulfate of potash equals 109, that with muriate equals 113, and that with kainit equals 135.

Inasmuch as sodium is useful when potassium is insufficient, the superiority of the kainit was doubtless due to the fact that it contained about twice as much soda as potash. It contained only a little magnesia.

If sulfur exerted any effect in the sulfate, it was apparently less than that exerted by the sodium in the muriate.

It is evident that magnesium was not deficient, otherwise the magnesium-potassium sulfate would scarcely have proved to have the least beneficial effect on the crops.

OBSERVATIONS ON THE TIME OF BLOOMING OF RICE FLOWERS[1]

JENKIN W. JONES[2]

INTRODUCTION

Prior to starting some hybridization experiments with rice, the writer made observations on the time of blooming of rice flowers, in order to determine the hours at which blooming is at a maximum and when pollen could be most easily collected for use in crossing.

The inflorescence of rice is a terminal panicle of perfect flowers. The one-flowered spikelet bears a branched stigma and six stamens.

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The lodicules are well developed. Früwirth, according to Pope (1)[3], observed the following sequence in the blooming of rice: "Flower began to open at 14 minutes after 10 o'clock; it was fully open at 14 minutes, 30 seconds, past 10; the anthers burst at 10.21; and the flower closed at 1:00 p. m." In California, the writer has observed that the flowers open more slowly, but the anthers free the pollen sooner than was the case in the flower observed by Früwirth. Rice normally is self-fertilized, but investigations have shown that cross-pollination occasionally may occur.

REVIEW OF LITERATURE

Sharngapani (2), in India, observed that the time at which the paddy flowers open differs with the time of the year when the paddy plant flowers. Aus, or early paddy, which is sown in April and May and flowers in July and August, opens about 7 a. m.; while sail, or transplanted paddy, which flowers in October, opens at about 9 a. m. He also observed that weather conditions at the time of flowering affect a good deal the time of opening, sunshine hastening the process and clouds and rain retarding it.

Thompstone (4) made observations on the blooming of rice flowers in Upper Burma and reports that the glumes open, the stamens hang out, and the feathery stigma protrude only once, for a short time in the early morning, usually between 7 and 10 a. m. He states also that dewy mornings appear to be most favorable; and flowering will then be at its maximum height about 8 to 9 a. m. As the dew gradually disappears the flowers will be found to be opening rapidly, but as the day begins to get bright, dry and warm, no more glumes open and those already opened close up again, the stamens by this time being dry and shriveled.

Torres (5) states that the rice flowers in the Philippines generally open between 9 and 11.30 a. m. on bright sunny days. At times, but very rarely, a few flowers will open when the sun peeps out in the afternoon of a cloudy day. Flowers which emerge from their sheath one day are sure to open up the following day, provided this is sunny. This is especially true of non-bearded varieties. Bearded varieties are known which open three days after emerging from the sheath.

Van der Stok (3) found that in Java rice flowers do not open before 6 a. m. or after 3:30 p. m.; that the greater number of blossoms opened between 10 to 12 o'clock but that also a large number opened between 9 to 10 a. m. and between 12 to 1 o'clock.

This brief review of the literature indicates that the maximum time

[3]Reference by number is to "Literature Cited," p. 669.

of blooming of rice flowers varies in different countries and in the same country under varying climatic conditions.

EXPERIMENTAL WORK

METHODS USED

The observations of the time of blooming of rice flowers reported in this paper were made in 1922, from August 15 to 17, and from September 14 to 18, inclusive, at the Biggs Rice Field Station, Biggs, California. The observations were made on early maturing and late maturing short-grain, and late maturing long-grain rices. The varieties included in these observations were growing in the nursery in rod-rows spaced three feet apart. Panicles of each variety which were being exserted from the sheath were numbered and tagged. The tagged panicles were inspected daily at 8 and 10 a. m., 12 m., 2 or 2:30, and 4 and 5 o'clock, p. m., and the flowers which had bloomed, or were in the process of blooming, were counted, recorded, and carefully clipped from the panicles. The writer is aware of the fact that a slight mechanical jar may cause wheat flowers to open, but the experience with and observation on rice in California indicate that the flowers of rice are not nearly so sensitive in this respect as those of wheat. It is believed that the careful clipping of the bloomed flowers from the panicle did not alter the time of blooming of the flowers remaining on the panicle.

THE TEMPERATURE DURING THE DAYS OF OBSERVATION

Observers have reported that the temperature and condition of the atmosphere have a marked influence on the time of blooming of rice. Therefore the temperature and the condition of the sky for the days on which observations on blooming were made are presented in Table 1. On August 15, 16 and 17 the maximum and minimum temperatures were lower, and the daily range in temperature less, than for the period from September 14 to 18, inclusive. The sky was clear and humidity low each day, and conditions were favorable for flowering.

Table 1.—*Maximum, minimum, and daily range in temperature, and condition of the sky, during the days on which observations were made on the time of blooming of rice flowers in 1922.*

Month and day		Temperature °F. Maximum	Minimum	Range	Sky condition
August	15	91	57	34	clear
	16	89	58	31	"
	17	89	54	35	"
September					
	14	102	60	42	"
	15	101	61	40	"
	16	98	62	36	"
	17	98	59	39	"
	18	97	59	38	"

TIME OF BLOOMING OF RICE FLOWERS

The data concerning the time of blooming of the several different varieties are assembled in Table 2. They may be briefly summarized and discussed according to types as follows:

Table 2.—*Summary of results of observations on the time of blooming of different classes and varieties of rice at the Biggs Rice Field Station, Biggs, California in 1922.*

Class and variety	C.I. No.	Number of flowers blooming between: 8 and 10 a.m.	10 a.m and 12m.	12m. and 2 p.m.	2 and 4 p. m.	4 and 5 p.m.	Total number of flowers
Early short-grain varieties		a		b	c	a	
Colusa	1600		5	51	16		72
Bomba	2085		1	47	1		49
Unnamed	2119		5	42	5		52
Unnamed	2120		0	27	0		27
Unnamed	2310		9	30	3		42
Geppu	2311		5	27	2		34
Total			25	224[b]	27[c]		276
Percentage			9.06	81.16	9.78		100
Late short grain varieties							
Shinriki	1642	0	2	210	112	6	330
Omachi	1573	3	18	198	23	2	244
Wataribune	1561	0	10	178	19	0	207
Total		3	30	586	154	8	781
Percentage		.38	3.84	75.03	19.72	1.03	100
Late long-grain varieties							
Unnamed	1241	0	49	136	3	0	188
Unnamed	1258	0	38	97	2	0	137
Unnamed	1288	0	6	107	10	0	123
Total		0	93	340	15	0	448
Percentage		0	20.76	75.89	3.35	0	100
Grand Total		3	148	1150	196	8	1505
Percentage		0.20	9.84	76.41	13.02	0.53	100

[a]No observations made.
[b]Observation between 12 m. and 2:30 p. m.
[c]Observation between 2:30 and 5 p. m.

Early Short-grain Varieties

The data for early short-grain varieties show that 25 flowers bloomed between 10 a. m. and 12 m.; 224 between 12 m. and 3:30 p. m., and 27 between 2:30 and 5 p.m. Of the 276 flowers observed, 81.16 per cent bloomed between 12 m. and 2:30 p. m. Approximately equal percentages of the remainder bloomed between 10 a. m. and 12 m., and between 2:30 and 5 p. m., respectively.

Late Short-grain Varieties

The data for the late short-grain varieties show that 3 flowers bloomed between 8 and 10 a. m.; 30 between 10 a. m. and 12 m.;

586 between 12 m. and 2 p. m.; 154 between 2 and 4 p. m., and 8 between 4 and 5 p. m. Of the 781 flowers observed, 75.03 percent bloomed between 12 m. and 2 p. m. and 19.72 per cent between 2 and 4 p. m., or a total of 94.75 percent of the flowers observed bloomed between 12 m. and 4 p. m. Of Shinriki, a larger number of flowers bloomed between 2 and 4 p. m. than of Omachi and Wataribune, but fewer flowers bloomed between 10 a. m. and 12 m.

Late Long-grain Varieties

The average results of observations on the late maturing long-grain varieties show that no flowers bloomed between 8 and 10 a. m.; 93 bloomed between 10 a. m. and 12 m.; 340 between 12 m. and 2 p. m.; and 15 between 2 and 4 p. m. Of the 448 flowers observed, 20.76 percent bloomed between 10 a. m. and 12 m. and 75.89 percent between 12 m. and 2 p. m ., or a total of 96,65 percent bloomed between 10 a. m. and 2 p. m.

SUMMARY

In summarizing the observations on the time of the blooming of rice flowers, as presented in Table 2, it is noted that over three-fourths of the rice flowers observed bloomed between 12 m. and 2 p. m., and that more flowers bloomed between 2 and 4 p. m. than between 10 a. m. and 12 m. Varietal differences appear to have some influence on the time of blooming. Fewer flowers of Shinriki bloomed before 12 m. and more after 2 p. m. than was the case with Omachi and Wataribune. Many more flowers of the long-grain varieties, C. I. Nos. 1241 and 1258, bloomed between 10 a. m. and 12 m. than of the short grain varieties.

Of the 1,505 flowers observed, 3 bloomed between 8 and 10 a. m.; 148 between 10 a. m. and 12 m.; 1,150 between 12 m. and 2 p. m.; 196 between 2 and 4 p. m., and 8 between 4 and 5 p. m. More than three-fourths of the flowers observed bloomed between 12 m. and 2 p. m., and a slightly larger number bloomed between 2 and 4 p. m. than between 10 a. m. and 12 m. It appears, therefore, that the maximum period of blooming of rice flowers in California is later in the day than in those other countries for which such data are available.

LITERATURE CITED

1. Pope, M. N. The mode of pollination in some farm crops. *In* Jour. Amer. Soc. Agron. 8:209–227. 1916.
2. Sharngapani, S. G. A few observations on paddy (*Oryza sativa*) crossing. *In* Agr. Jour. India 19:48–50. 1924.
3. Stok, J. E. van der. Onderzoekingen omtrent rijst en tweede gewassen (Experiments with rice and secondary crops). Meded. Dept. Landb. (Dutch East Indies) no. 12, 243 p. 1910.

4. THOMPSTONE, E. Some observations on Upper Burma paddy. (Grown under irrigation). *In* Agr. Jour. India 10:26–53. 1915.
5. TORRES, J. P. Some notes on rice hybridization work. Philippine Agr. Rev. 16:46–48. 1923.

RELATION OF SEED SIZE TO THE YIELD OF SMALL GRAIN CROPS[1]

T. A. KIESSELBACH[2]

INTRODUCTION

Studies concerning the relation of seed grades to the grain yields of small grain crops have been so varied and of such long duration at the Nebraska Agricultural Experiment Station that a summary of results would seem to be of general interest. It is the purpose of this paper to develop the principles involved in this problem, and to summarize all the data which are available to date.

The practical significance of such investigations depends upon the degree to which the methods of comparison approach applicability to farm conditions. Those field comparisons are probably of greatest importance which include the practice most commonly in vogue among crop producers. A sound recommendation regarding the principle of the mechanical grading of seed can hardly be made from a mere comparison of extremes. The vital question is, how does the graded compare with the ungraded seed. A matter of only second interest is the comparative performance of relatively light weight seed resulting from unfavorable growth conditions with seed of normal development. Correct information on these points may be of material value to the farmer.

The methods which have been reported in the literature for selecting seed grades may be classified as follows: (1) hand selection, (2) fanning mill separation, (3) specific gravity separation by use of a salt solution, and (4) choice of distinct grades resulting from difference in the favorableness of growth conditions.

The rate of spacing of the seed has varied greatly in different experiments which may be classified as follows: (1) those in which seed are spaced far apart to permit maximum development of individual plants, and (2) those in which seed are planted close, testing the grades in either, (a) equal numbers, (b) equal weights, or (c) equal volumes per acre.

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[2]Agronomist.

The comparisons have all been made in either (1) small nursery plats, (2) larger field plats, or (3) in pots filled with soil or culture solution.

EXPERIMENTAL WORK

The presentation of the Nebraska data will be in the sequence of the least comparable to the most comparable with farm field conditions. All tests were made in the field, in either nursery or larger field plats. Nursery plats were hand seeded, and since 1911 consisted of replicated 3-row blocks, of which only the center rows are used for comparison. The field plats, one-thirtieth acre in size, have been in duplicate since 1909 and were seeded with a standard grain drill.

YIELD PER PLANT FROM LARGE AND SMALL SEED SPACED TO PERMIT MAXIMUM DEVELOPMENT

The inherent yielding capacity, unhampered by competition with adjacent plants was determined for large and small hand selected seed of winter and spring wheat and oats by spacing 6 inches apart in nursery blocks. The individual kernel weights of the small seed planted for these crops were only 37, 59, and 46 percent as great respectively as for the large seed. Each test was systematically replicated 5 times. All plants were pulled by hand when ripe, and individual counts and measurements were made. The average results for the four year period, 1920-1923, are given in Table 1. For the winter wheat, spring wheat, and oats the small seed yielded, respectively 81.4, 82.1, and 82.6 percent as much as the large. Plants from the small seed stooled less, were shorter, slightly later ripening, and lower in grain yield.

TABLE 1.—*Effect of size of seed on size and yield of small grain plants when spaced to permit maximum individual development. Four year average, 1920–1923.*

Seed planted		Crop harvested					
Grade of seed	Weight per 100	Date in head	Date ripe	Number of plants	Height of plants Inches	No. of heads per plant	Yield of grain per plant Grams
Turkey Red winter wheat.							
Large.......	3.57	6–12	7–3	259	35.2	13.0	4.25
Small.......	1.32	6–13	7–4	253	33.5	11.9	3.46
Ratio.......	0.37	——	——	——	0.95	0.92	0.81
Java spring wheat.							
Large.......	2.78	6–17	7–9	400	31.2	5.24	2.028
Small.......	1.64	6–18	7–9	362	29.5	4.52	1.666
Ratio.......	0.59	——	——	——	0.95	0.86	0.82
Kherson oats.							
Large.......	2.56	6–14	7–6	451	29.2	4.89	4.729
Small.......	1.25	6–16	7–7	466	28.2	4.38	3.906
Ratio.......	0.49	——	——	——	0.97	0.90	0.83

EQUAL WEIGHTS VERSUS EQUAL NUMBERS OF LARGE, SMALL AND UNSELECTED SEED

Winter wheat, spring wheat, and oats have been included in this test. A summary of the results is shown in Tables 2 and 3. Comparisons have been made in 3-row nursery plats replicated 10 times annually. The procedure was to plant the large seed at a rate approxi-

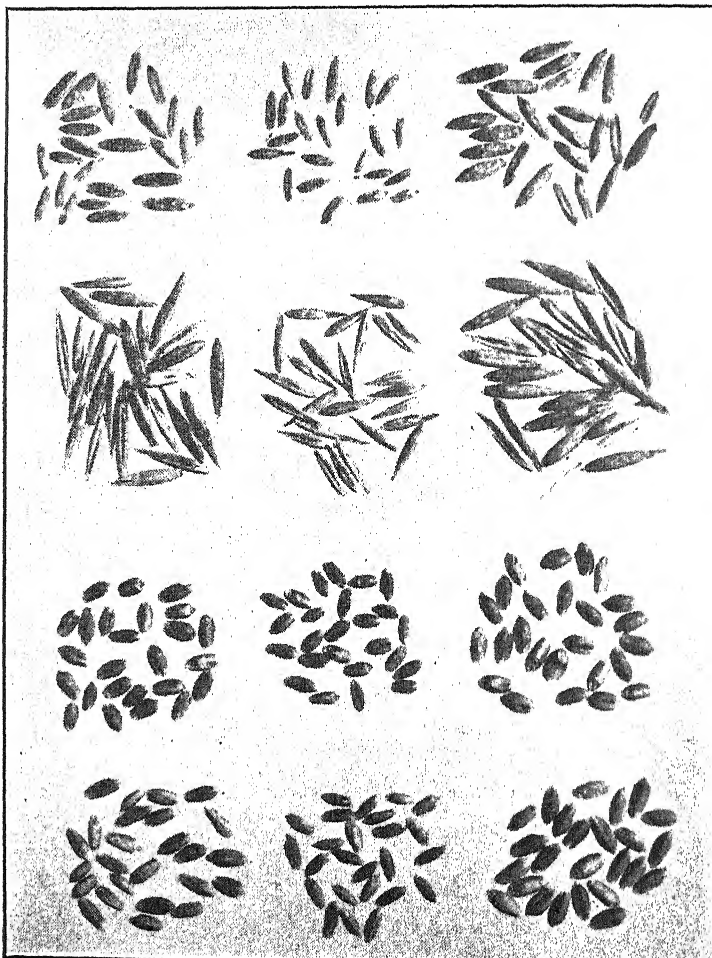

Fig. 1 Representative seed grades selected by hand and compared for yield by several methods of testing. (Tables 1 to 3)

Left to right: Bottom row (1) Turkey winter wheat,—ungraded, small, large.
(2) Java spring wheat—ungraded, small, large.
(3) Kherson oats—ungraded, small, large.
(4) Same as 3 with hulls removed.

mately normal in the farm practice of this region. This rate actually amounted to an average of six pecks per acre for winter and spring wheat, and ten pecks for oats. The small and the unselected seed were then planted in comparison with the large by seeding in both equal numbers and equal weights of seed per unit area.

TABLE 2.—*Comparative yields from large, small, and unselected seed of small grain crops when planted in equal numbers and also equal weights of seed per acre at an optimum rate for large seed.*

Grade of seed	Equal numbers of seed: Seed planted per acre, Number	Equal numbers of seed: Seed planted per acre, Weight Pounds	Equal numbers of seed: Yield per acre Bushels	Equal weights of seed: Seed planted per acre, Number	Equal weights of seed: Seed planted per acre, Weight Pounds	Equal weights of seed: Yield per acre Bushels
Turkey Red winter wheat. 10 years, 1911, 1914–1916, 1918–1923						
Large.........	1,308,107	90	35.7	1,308,107	90	35.7
Small.........	1,308,107	54	32.8	2,222,359	90	34.3
Unselected.....	1,308,107	73	34.5	1,613,780	90	36.8
Java spring wheat. 9 years, 1915–1923						
Large.........	1,452,000	89	13.3	1,452.000	89	13.3
Small.........	1,452,000	55	11.3	2,458,599	89	12.0
Unselected.....	1,452,000	71	12.7	1,796,094	89	13.4
Kherson oats. 12 year average, 1912–1923						
Large.........	1,500,642	78	43.3	1,500,642	78	43.3
Small.........	1,500,642	45	40.6	2,632,897	78	42.8
Unselected[a]....	1,500,642	58	41.7	2,016,011	78	43.0

[a]The test in equal numbers of unselected Kherson oats was made during only the last 7 years. The results for this grade in this 12-year summary are calculated on the basis of the 7-year comparative performance.

TABLE 3—*Relative results from large, small, and unselected seed of small grain crops when planted in equal numbers and also equal weights of seed per acre, at an optimum rate for large seed.*[a]

Grade of seed	Equal numbers of seed: Seed planted per acre, Number Pct.	Equal numbers of seed: Seed planted per acre, Weight Pct.	Equal numbers of seed: Yield per acre Pct.	Equal weights of seed: Seed planted per acre, Number Pct.	Equal weights of seed: Seed planted per acre, Weight Pct.	Equal weights of seed: Yield per acre Pct.
Turkey Red winter wheat. Ten years, 1911, 1914–1916, and 1918–1923						
Large.................	100	100	100	100	100	100
Small.................	100	60	91.9	170	100	96.1
Unselected............	100	81	96.6	123	100	103.1
Java spring wheat. 9 years, 1915–1923						
Large.................	100	100	100	100	100	100
Small.................	100	62	85	169	100	90.2
Unselected............	100	80	95.5	124	100	100.8
Kherson oats. 12 years, 1912–1923						
Large.................	100	100	100	100	100	100
Small.................	100	58	93.8	175	100	98.8
Unselected............	100	74	96.3	134	100	99.3
Summary for the three cereals						
Large.................	100	100	100	100	100	100
Small.................	100	60	90.2	171	100	95.0
Unselected............	100	78	96.1	127	100	101.1

[1]These data are calculated from those presented in Table 2.

Turkey Red winter wheat. When equal numbers of seed were sown the comparative grain yields per acre from large, small, and unselected seed during a ten year period were 100, 92 and 97 percent; whereas when equal weights of seed were used the corresponding yields were 100, 96, and 103 percent.

Java spring wheat. Comparing large, small, and unselected seed of Java spring wheat by seeding equal numbers of seed per unit area, the respective relative grain yields during a nine year period were 100, 85, and 96 percent; while the corresponding yields were 100, 90, and 101 percent seeded at equal weights per acre.

Kherson oats. Seeded in equal numbers, the large, small, and unselected seed of Kherson oats gave the respective relative yields during a twelve year period of 100, 94, and 96 percent. Equal weights of these respective seed grades gave the relative yields of 100, 99, and and 99 percent.

Average of the three cereal crops. Combining the results for winter wheat, spring wheat, and oats shows that: Small seed weighing 60 percent as heavy as the large, yielded 10 percent less than the large when compared in equal numbers, and 5 percent less when equal weights of the seed were sown. The unselected seed, averaging 78 percent as heavy as the large, yielded 4 percent less than the large seed when compared in equal numbers; whereas the yield was 1 percent higher than that from the large seed when equal weights of seed were sown per acre.

COMPARISON OF FANNING MILL GRADES OF WINTER WHEAT AND OATS SEEDED AT A UNIFORM VOLUME

Winter wheat. Annual separations were made from a pure line (Nebraska No. 6) of Turkey Red winter wheat during the five years, 1919-1923. Four grades were included in each test; viz., (1) largest one-fourth, and (2) smallest one-fourth, as separated on an ordinary screen fanning mill; (3) heaviest one-fourth, and (4) lightest one-fourth as separated on a wind blast gravity grader. A fifth grade of light seed which had resulted either from severe rusting or premature harvesting of the growing crop was included. All of these grades were compared with the original wheat corresponding with that from which they were selected. The tests were made in duplicated one-thirtieth acre field plats drilled at a uniform volume of five pecks per acre. The results are shown in Table 4.

Based on the original wheat as 100 percent, the five year average yields as shown in Table 4 were: (1) unselected, 100 percent; (2) largest one-fourth, 101.9 percent; (3) heaviest one-fourth, 98.7 per-

TABLE 4—*Effect of fanning mill grading upon the yield of a pure strain of Turkey Red winter wheat, (Nebraska No. 6). Five year average, 1919–1923.*

Character of seed	Test weight of seed planted	Plant height	Summary for period: Date in head	Date ripe	Weight per bu.	Yield per acre: Actual	Relative
	Pounds	Inches			Pounds	Bu.	Pct.
Original untreated...........	58.5	36.7	6/2	7/1	58.5	31.1	100.0
Largest ¼ (fanning mill).....	59.8	36.9	6/2	7/1	58.7	31.7	101.9
Smallest ¼ (fanning mill).....	58.0	37.3	6/2	7/1	58.2	30.5	98.1
Heaviest ¼ (wind blast)......	60.0	37.0	6/2	7/1	58.3	30.7	98.7
Lightest ¼ (wind blast)......	57.2	36.6	6/2	7/1	58.0	30.0	96.5
Shrunken seed[a]	54.5	36.7	6/2	7/2	58.1	31.8	102.3

[a]Note: Seed from either badly rusted or immaturely harvested wheat.

cent; (4) average for largest and heaviest grades, 100.3 percent; (5) smallest one-fourth, 98.1 percent; (6) lightest one-fourth, 96.5 percent; (7) average for smallest and lightest grades, 97.3 percent, and (8) light grade shrunken seed, 102.3 percent. Thus, the maximum average increase from grading was 1.9 percent and the greatest reduction from discarding the best three-fourths of the seed was 3.5 percent.

TABLE 5—*Yields of light and heavy seed wheat as separated by a gravity fanning mill. Seventeen years, 1900–1911 and 1919–1923.*

Kind of seed planted	Yield per acre[a]: 1900–1911 Big Frame	1900–1911 Turkey Red	Ave.	1919–1923 Turkey Red	Ave. for 17 years[b] Actual Bushels	Relative Per cent
Original unselected...	32.6	34.4	33.5	31.1	32.8	100.0
Heaviest one-fourth..	32.4	35.4	33.9	30.7	32.9	100.3
Lightest one-fourth...	31.0	35.1	33.0	30.0	32.1	98.0

[a]Unduplicated plats during first 10 years.
[b]The seventeen-year average represents the yield for two varieties during the first twelve years, and one variety thereafter.

In an earlier test during 1900-1911, the results of which are shown in Table 5, two varieties of winter wheat gave the following relative results when graded by weight on a wind blast gravity separator: (1) original unselected seed, 100 percent; (2) heaviest one-fourth seed, 101.2 percent; and (3) lightest one-fourth seed, 98.5 percent. Including the 1919-1923 results for Turkey Red, these relative yields were, respectively, 100, 100.3, and 98.0 percent.

Oats. The effect of seed grading was studied during six years, 1917 and 1919-1923, upon common Kherson oats, which is a natural mixture of strains and also upon a pure line selection from this variety known as Nebraska No. 21. Separations and yield tests were made after the same plan described for the five year winter wheat test on page 674. The results shown in Table 6, indicate no striking difference in the reaction to grading by the commercial variety and the

TABLE 6—*Relative effect of fanning mill grading upon common Kherson oats, versus a pure line of Kherson oats.*[a] *Six year average, 1917– and 1919–1923.*

Character of seed planted Grade[b]	Weight per 1000 seed Grams	Weight per bushel Pounds	Date in head	Date ripe	Height In.	Grain harvested Weight per bushel Lbs.	Yield per acre Actual Bu.	Yield per acre Relative Pct.
Common Kherson								
Original ungraded.....	16.90	29.5	6/12	7/4	30.6	30.9	59.6	100.0
Heaviest one-fourth...	19.16	31.3	6/11	7/4	30.1	31.0	59.4	99.7
Lightest one-fourth....	16.73	29.0	6/12	7/5	30.5	30.7	57.8	97.0
Largest one-fourth....	22.39	30.0	6/12	7/4	30.6	30.9	59.3	99.5
Smallest one-fourth...	12.81	30.0	6/12	7/4	30.2	31.1	58.9	98.8
Nebraska No. 21 Kherson								
Original ungraded.....	18.23	29.8	6/13	7/4	31.7	31.1	60.1	100.0
Heaviest one-fourth...	19.12	30.8	6/13	7/4	31.5	31.4	60.9	101.3
Lightest one-fourth...	16.82	29.5	6/13	7/5	31.2	31.4	58.9	98.0
Largest one-fourth....	23.29	30.8	6/13	7/4	31.6	31.5	57.8	96.2
Smallest one-fourth...	15.55	30.5	6/13	7/5	30.9	31.1	58.1	96.7
Average for both sorts								
Original ungraded.....	17.56	29.6	6/12	7/4	31.1	31.0	59.8	100.0
Heaviest one-fourth...	19.14	31.0	6/12	7/4	30.8	31.2	60.2	100.5
Lightest one-fourth...	16.77	29.2	6/12	7/5	30.8	31.0	58.3	97.5
Largest one-fourth....	22.84	30.4	6/12	7/4	31.1	31.2	58.5	97.8
Smallest one-fourth...	14.18	30.2	6/12	7/5	30.5	31.1	58.5	97.8

[a]All grades seeded in duplicate with drill set at ten pecks per acre.
[b]The heavy and the light grades were separated with a windblast fanning mill while the large and the small grades were separated by an ordinary screen fanning mill.

pure line strain. As an average for the two sorts, the (1) ungraded seed yielded 59.8 bushels per acre; (2) heaviest one-fourth, 60.2 bushels, (3) largest one-fourth, 58.5 bushels; (4) lightest one-fourth, 58.3 bushels, and (5) smallest one-fourth 58.5 bushels. The corresponding relative yields were 100, 100.5, 97.8, 97.5, and 97.8 percent.

TABLE 7—*Effect of fanning mill grading upon the yield of Kherson oats. Average for eighteen years, 1905–1917 and 1919–1923.*

Grade of seed planted	Yield of grain per acre Actual Bushels	Yield of grain per acre Relative Per cent
Original unselected............................	56.3	100.0
Heaviest one-fourth............................	56.8	100.9
Lightest one-fourth............................	55.9	99.3

In a test extending over 18 years, 1905-1917, and 1919-1923, the results of which are shown in Table 7, three fanning mill grades of Kherson oats gave the following results: (1) original unselected, 56.3 bushels (2) heaviest one-fourth, 56.8 bushels; and (3) lightest one-fourth, 55.9 bushels. Corresponding relative yields were 100, 100.9, and 99.3 percent.

HISTORICAL SUMMARY OF THE GRAIN YIELDS FROM SEED GRADES OF SMALL GRAIN CROPS

From a review of the literature, it is concluded that practically all investigations reporting the relative grain yields from different grades of small grain seed fall into one or more of the groups which have been used to classify the Nebraska tests in Tables 1 to 7. With the exceptions of pot experiments, all such investigations that have been found in the literature are brought together in Tables 8 to 12. Pot experiments with winter wheat conducted by Voelcker (27, 28, and 29) during two years, (1902 and 1903) and Williams (32) during one year (1905), gave respective average increases in grain yield of four and nineteen percent for small over large seed. References not reporting

TABLE 8—*Relative yields of large and small seeds, space-planted to permit maximum individual plant development.*

Crop	Investigator	Duration of test	Relative yields Large seed	Small seed
		Years	Per cent	Per cent
Winter wheat	Cobb (4)	3	100	83
Winter wheat	Kiesselbach (12)	4	100	81
Spring wheat	Bolley (2)	4	100	90
Spring wheat	Kiesselbach and Helm (11)	1	100	64
Spring wheat	Kiesselbach and Lyness (13)	4	100	82
Oats	Kiesselbach and Helm (11)	1	100	84
Oats	Kiesselbach and Lyness (13)	4	100	83
Oats	Williams and Welton (34)	5	100	94
Winter wheat	Percival (22)	5	100	69
	Average.		100	81

TABLE 9—*Relative yields from large and small seeds when planted in equal numbers, at a rate normal for the large seeds.*

Crop	Investigator	Duration of test	Yield per acre Large or heavy seed	Small or light seed	Ratio small to large
		Yrs.	Bu.	Bu.	
Winter wheat	Kiesselbach and Helm (11)	4	43.20	41.30	.96
Winter wheat	Kiesselbach (12)	10	35.7	34.3	.96
Winter wheat	Montgomery (20)	1	47.17	43.81	.93
Winter wheat	Soule and Vanatter (24)	3	26.60	23.42	.88
Winter wheat	Zavitz (35)	6	46.90	40.40	.86
Spring wheat	Kiesselbach and Helm (11)	2	18.30	14.20	.78
Spring wheat	Kiesselbach and Lyness (13)	9	13.3	12.0	.90
Spring wheat	Zavitz (35)	8	21.70	18.00	.83
Oats	Kiesselbach and Lyness (13)	12	43.3	42.8	.99
Oats	Kiesselbach and Ratcliff (14)	5	46.10	41.00	.89
Oats	Montgomery (20)	1	48.32	43.85	.91
Oats	Zavitz (36)	7	54.10	46.60	.86
Oats	Zavitz (36)	12	70.50	53.86	.76
Barley	Soule and Vanatter (24)	1	36.30	28.70	.79
Barley	Zavitz (35)	6	53.80	50.40	.94
Rye	Nielson (21)	4	26.70	25.70	.96
	Average		39.50	35.02	.89

TABLE 10—*Relative yields from unselected and large and small or heavy and light seeds as separated by a fanning mill and planted in equal volumes*

Crop	Investigator	Duration of test	Yield per acre: Unselected seed	Yield per acre: Large seed	Yield per acre: Small seed	Ratio unselected to large	Ratio small to large
		Years	Bushels	Bushels	Bushels		
Winter wheat	Kiesselbach and Helm (11)	4	45.2	43.2	43.2	1.05	1.00
Winter wheat	Kiesselbach (12)	10	36.8	35.7	34.3	1.03	.96
Oats	Kiesselbach and Ratcliff (14)	5	45.2	46.1	46.1	.98	1.00
Oats	Kiesselbach and Lyness (13)	12	43.0	43.3	42.8	.99	.99
Spring wheat	Kiesselbach and Helm (11)	2	15.2	14.1	13.9	1.08	.99
Spring wheat	Kiesselbach and Lyness (13)	9	13.4	13.3	12.0	1.01	.90
		Average	33.1	32.6	32.1	1.02	.97

TABLE 11—*Relative yields from large and small or heavy and light seeds as separated by a fanning mill and planted in equal volumes.*

Crop	Investigator	Duration of test	Yield per acre: Unselected seed	Yield per acre: Heavy or Large seed	Yield per acre: Light or Small seed	Ratio unselected to large seed	Ratio small to large
		Years	Bushels	Bushels	Bushels		
Winter wheat	Georgeson (6)	4	28.97	29.15	27.60	.99	.95
Winter wheat	Kiesselbach and Helm (11)	12	33.50	33.90	33.00	.99	.97
Winter wheat	Kiesselbach (12)	5	31.1	30.9	30.8	1.01	1.00
Winter wheat	Hickman (9)	4	13.37	14.00	13.74	.96	.98
Winter wheat	Hickman (10)	9	16.33	17.06	16.21	.96	.95
Winter wheat	Montgomery (18)	8	30.00	30.20	29.00	.99	.96
Winter wheat	Sanborn (23)	4	16.42	17.66	14.98	.93	.85
Oats	Georgeson (7)	8	29.89	30.90	27.50	.97	.89
Oats	Kiesselbach and Ratcliff (14)	12	54.62	55.45	54.71	.99	.99
Oats	Kiesselbach and Ratcliff (14)	4	41.77	39.70	43.37	1.05	1.09
Oats	Kiesselbach and Lyness (13)	18	56.3	56.8	55.9	.99	.98
Oats	Montgomery (18)	3	65.40	65.80	64.30	.99	.98
Oats	Williams (31)	7	44.77	46.31	42.63	.97	.92
Oats[a]	Williams and Welton (34)	4	58.23	58.98	56.66	.99	.96
Oats	Welton and Gearhart (30)	6	57.63	57.88	54.92	1.00	.95
		Average	38.55	38.98	37.69	.98	.96

[a]Average for equal volumes and equal numbers.

TABLE 12—*Relative yields from large and small seeds when planted in equal weights, at a rate normal for the large seeds.*

Crop	Investigator	Duration of test Years	Yield per acre Large or heavy seed Bu.	Yield per acre Small or light seed Bu.	Ratio small to large
Winter wheat	Georgeson (6)	4	29.15	27.60	.95
Winter wheat	Grenfall (81)	1	9.70	7.50	.77
Winter wheat	Kiesselbach and Helm (11)	12	33.90	33.00	.97
Winter wheat	Kiesselbach (12)	5	30.9	30.8	1.00
Winter wheat	Hickman (9)	4	14.00	13.74	.98
Winter wheat	Kickman (10)	9	17.06	16.21	.95
Winter wheat	Lyon (17)	4	24.50	23.70	.97
Winter wheat	Latta (15)	3	30.54	27.94	.91
Winter wheat	Montgomery (18)	8	30.20	29.00	.96
Winter wheat	Sanborn (23)	4	17.66	14.98	.85
Winter wheat	Williams (32)	2	22.64	22.17	.98
Winter wheat	Williams and Welton (33)	7	31.26	31.32	1.00
Oats[a]	Burnett (3)	3	49.00	48.75	.99
Oats	Boss (2)	1	64.09	54.59	.85
Oats	Georgeson (7)	8	30.90	27.50	.89
Oats (Kherson)	Kiesselbach and Ratcliff (14)	12	55.45	54.71	.99
Oats (American Banner)	Kiesselbach and Ratcliff (14)	4	39.70	43.37	1.09
Oats	Kiesselbach and Lyness (13)	18	56.8	55.9	.98
Oats	Montgomery (18)	3	65.80	64.30	.98
Oats[b]	Williams (31)	7	46.31	42.63	.92
Oats	Williams and Welton (34)	4	58.98	56.66	.96
Rye	Nielson (21)	7	38.2	38.80	1.02
Barley	Voelcker (29)	1	32.10	36.40	1.13
	Average		36.00	34.9	.96

[a]Average of two grades for each yield.
[b]Average data for equal volumes and equal numbers.

the grain yields from original comparative seed grade tests with small grain crops are not cited in this review.

Summarizing all available published field data dealing with the grain yields from seed grades of small grain crops (Tables 8 to 12) the following indications are apparent.

(1) When the space planting was such as to permit maximum development, the individual plant grain yield was 19 percent less for the small than for the large seed. This difference is due to the immediate advantage of a greater reserve food supply in the larger seed which results in a more vigorous initial growth..

(2) When planted in equal numbers at a rate optimum for the large seed, the small seed yielded 11 percent less grain per acre than the large.

(3) When planted in equal weights at a rate optimum for the large seed, the small seed yielded three percent less, and the unselected seed yielded two percent more per acre than the large seed. The relatively low yield of plants from small seed was largely overcome by planting a greater number of seeds.

(4) When comparing fanning mill grades of large and small seeds by planting in equal volumes with a grain drill set at a uniform rate, the small or light seed averaged four percent less grain per acre than the large or heavy seed. The original unselected seed yielded two percent less than the large.

SUMMARY OF NEBRASKA TESTS

Where tests were made with hand selected large and small seed which represented extreme grades of the three cereals, winter wheat spring wheat, and oats, small seed yielded (1) eighteen percent less than large, when spaced to permit maximum individual plant development, (2) ten percent less when equal numbers of seed were sown per acre at an optimum rate for the large seed, and (3) five percent less when equal weights of seed were sown per acre at an optimum rate for the large seed. When unselected seed was used it yielded (1) four percent less than the large when equal numbers were sown per acre, and (2) one percent less when equal weights of seed were sown.

A comparison of the large with the unselected seed is of the greater importance from the farmer's standpoint.

Comparing fanning mill grades of winter wheat during a seventeen year period, the heaviest one-fourth yielded 0.3 percent more, and the lightest one-fourth two percent less than the unselected.

Kherson oats was separated into the heaviest one-fourth, and the lightest one-fourth and compared with the original unselected seed during eighteen years. The heaviest one-fourth yielded 0.9 percent more, and the lightest one-fourth yielded 0.7 percent less than the unselected.

In general, the work at the Nebraska station indicates that there will be no material or practical gain in the grain yield, under farm conditions, from the practice of grading small grain seed which is reasonably free from trash and inert matter.

Comparative results have been found to vary greatly with the manner of testing.

LITERATURE CITED

1. Bolley, H. L. Work with wheat in 1900. N. D. Agr. Exp. Sta. 11th Ann. Rpt., pp. 28–32. 1901.
2. Boss, Andrew. Heavy versus light oats for seed. Minn. Agr. Exp. Sta. Bul. 31. p. 213. 1893.
3. Burnett, L. C. Some data for oat growers. Ia. Agr. Exp. Sta. Bul. 128. pp. 105–110. 1912.
4. Cobb, N. A. Seed wheat. *In* Agr. Gaz. N. S. W. 15: 145. 1903.
5. Georgeson, C. G., Cottrell, H. M. and Shelton, Wm. Experiments with oats. Kan Agr. Exp. Sta. Bul. 13. pp. 59–60. 1890.

6. GEORGESON, C. G. Experiments with wheat. Kan. Agr. Exp. Sta. Bul. 59. p. 99. 1896.
7. ———. Experiments with oats. Kan. Agr. Exp. Sta. Bul. 74. pp. 199–200. 1897.
8. GRENFELL, J. F. Some experiments with wheat. *In* Agr. Gaz. N. S. W. 12:1053. 1901.
9. HICKMAN, J. F. Field experiments with wheat. Ohio Agr. Exp. Sta. Bul. 82. p. 231. 1897.
10. ———. Field experiments with wheat. Ohio Agr. Exp. Sta. Bul. 129. p. 25. 1901.
11. KIESSELBACH, T. A. and HELM, C. A. Relation of size of seed and sprout value to the yield of small grain crops. Nebr. Agr. Exp. Sta. Res. Bul. 11. 1917.
12. KIESSELBACH, T. A. Winter wheat investigations. Nebr. Agr. Exp. Sta. Res. Bul. (In preparation) 1924.
13. ——— and LYNESS, W. E. Spring small grains. Nebr. Agr. Exp. Sta. Bul. 201. (In press) 1924.
14. ——— and RATCLIFF, J. A. Oat investigations. Nebr. Agr. Exp. Sta. Bul. 160. 1917.
15. LATTA, W. C. Experiments with wheat. Ind. Agr. Exp. Sta. Bul. 36. p. 115. 1891.
16. LYON. T. L. The adaptation and improvement of winter wheat. Nebr. Agr. Exp. Sta. Bul. 72. 1902.
17. ———. Improving the quality of wheat. U. S. Dept. Agr., Bur. Plant Ind. Bul. 78. Pt. II, pp. 49–75. 1905.
18. MONTGOMERY, E. G. The use of the fanning mill for selecting seed wheat and oats. Nebr. Agr. Exp. Sta. Bul. 104. p.32. 1908.
19. ———. Methods for testing the seed value of light and heavy kernels of cereals. *In* Proc Amer. Soc. Agron. 2:59–70. 1910.
20. ———. Competition in cereals. Nebr. Agr. Exp. Sta. Bul. 127. pp. 14–15. 1912.
21. NIELSON, P. Culture experiments with rye. Tidsskr. Landbr. Planteavl. 1:1–130. 1895. (Abs *in* Exp. Sta. Rec. 7:204–205).
22. PERCIVAL, JOHN. The Wheat Plant. pp. 425–427. Buckworth and Co. London. 1921.
23. SANDBORN, J. W. Seed selection. Utah Agr. Exp. Sta. 4th. Ann. Rpt. pp. 168-169. 1893.
24. SOULE, A. M. and VANNATTER, P. O. Seed selection. Tenn. Agr. Exp. Sta. Bul. v. 16, no. 4. p. 77. 1903.
25. —————. Winter wheat. Tenn. Agr. Exp. Sta. Bul. v. 14, no. 2. pp. 42–45. 1901.
26. —————. Winter cereals and legumes. Tenn. Agr. Exp. Sta. Bul. v. 14, no. 3. p. 5. 1901.
27. VOELCKER, J. A. Head versus tail corn for seed wheat. *In* Jour. Roy. Agr. Soc. Eng. 63:353. 1902.
28. ———. Head versus tail corn for seed wheat. *In* Jour. Roy. Agr. Soc. Eng. 64:354. 1903.
29. ———. Field experiments. *In* Jour. Roy. Agr. Soc. Eng. 67:282–310. 1906.

30. WELTON, F. A. and GEARHART, C. A. Experiments with oats. Ohio Agr. Exp. Sta. Mo. Bul. v. 1, no. 2. 1916.
31. WILLIAMS, C. G. Ten years' experiments with oats. Ohio Agr. Exp. Sta. Bul. 138. p. 48. 1903.
32. ———. Experiments with winter wheat. Ohio Agr. Exp. Sta. Bul. 165. pp. 56–59. 1905.
33. WILLIAMS, C. G. and WELTON, F. A. Wheat experiments. Ohio Agr. Exp. Sta. Bul. 231. p. 7. 1911.
34. ———. Experiments with oats. Ohio Agr. Exp. Sta. Bul. 257. pp. 66–67. 1913.
35. ZAVITZ, C. A. Seed grain selection. *In* Rpt. Ont. Dept. Agr. v. 2, pt. 1. p. 87. 1907.
36. ———. Continuous selection of seed oats. *In* Rpt. Ont. Dept. Agr. v. 1, p. 18. 1908.

BOOK REVIEW

NATIVE AMERICAN FORAGE PLANTS

By Samson, Arthur W. John Wiley and Sons Inc. 435 p. 199 fig. New York and London, 1924.

The title of this book is much broader than its content, as practically all of the plants described are those of the western half of the United States and of these a goodly number are not truly native, that is endemic. Chapters I to IV, pages 1 to 85, deal respectively with the following topics: Pasture Forage and Animal Nutrition; How Plants Live, Grow and Reproduce; Environment of Range and Pasture Plants and Forces that Influence them; Classification, Collection and Preservation of Plant Specimens. These chapters are apparently intended primarily as an aid to the public clientele, namely the ranchmen. The remainder of the book consists entirely of descriptions and economic data of the many western range plants on which domestic animals feed, together with a list of those avoided or rarely eaten and incidental mention of those with poisonous properties. This portion of the book brings together much information found only in many scattered papers together with a mass of new data based on the author's extensive studies. For each of the more important species a photographic illustration of the plant together with a map showing its range is provided. A great number of new "common" names for the plants are proposed, mostly translations of the scientific names. The book will prove most useful to all students of western range plants, and should be very helpful to ranchmen who desire better knowledge of the plants which sustain their herds and flocks. C. V. Piper.

AGRONOMIC AFFAIRS

NOTES AND NEWS

Dr. J. G. Lipman, Director of the New Jersey Agricultural Experiment Stations, returned from Europe on June 27. Dr. Lipman was elected President of the International Association of Soil Science and, as Chairman of the American Committee, will be responsible for planning the organization of the next international congress of the Association, which it was voted to hold in the United States, probably in 1927. While in Italy, the delegates to the Association were received by the King and Queen of Italy, the Prime Minister, the Minister of Agriculture, the Mayor of the City of Rome, and others. Through the American Embassy, an audience with the Pope was also arranged. On the return trip, Dr. Lipman stopped at Florence, Vienna, Berlin and Brussels; also in London and at Harpenden, where he was one of the speakers at the field day meeting at the Rothamsted Station, on June 18, the same date as the field day meeting at his own College at New Brunswick, N. J.

Dr. E. O. Fippin has gone to Haiti, where he will serve as chief in agronomy and director of the experiment station in the newly organized School of Agriculture and Agricultural Experiment Station.

A note to the effect that A. F. Kidder had resigned as agronomist of the Louisiana College of Agriculture, which appeared in No. 7, of Volume 50 of the Experiment Station Record, is incorrect. Professor Kidder writes that he has not resigned and asks that information to this effect be given in this JOURNAL.

Professor G. H. Cutler, of the Department of Field Husbandry of the University of Alberta at Edmonton, Alberta, Canada, has been given a year's leave of absence for graduate study at the University of Wisconsin.

Professors George Stewart, of the Department of Agronomy at the Utah Agricultural College, and O. O. Churchill, of the North Dakota Agricultural College, are spending a year's leave of absence in graduate study at the University of Minnesota.

Arthur H. Post has been appointed Assistant Professor of Agronomy at the Montana Agricultural College at Bozeman.

Dean A. R. Mann, of the New York State College of Agriculture at

Cornell University has been given a two-year's leave of absence, during which he will serve as Director for Agriculture of the International Educational Board. He sailed for Europe on August 16, and will establish headquarters at the International Institute of Agriculture at Rome. He will arrange for international cooperation in agricultural education, research and practice. During his absence, the administration of the college at Cornell will be in the hands of a Committee on Administration composed of the three directors, of resident teaching, of experiment stations and of extension work, respectively.

C. B. Hutchison has resigned as Director of the Davis Branch of the College of Agriculture of the University of California, in order to become the European resident representative for agriculture of the International Educational Board.

On August 11, Professor E. A. Spragg, of the Department of Farm Crops of the Michigan Agricultural College, Mrs. Spragg, and their son Glenn, were instantly killed when their automobile was struck by a railroad train. Professor Spragg had been an active member of this Society since its first organization, and his many friends will deeply regret his untimely and tragic death.

Professor M. A. MacCall, formerly Superintendent of the dry-farming substation at Lind, Washington, and later of the Department of Agronomy of the State College at Pullman, Washington, has been appointed agronomist in the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture, to fill the vacancy caused by the appointment of C. W. Warburton as Director of Extension Work for the Department.

ANNOUNCEMENT OF THE PROGRAM FOR THE ANNUAL MEETING OF THE SOCIETY

The annual meeting of the Society of Agronomy will be held in Washington on Monday and Tuesday, November 11th and 12th, 1924, immediately preceding the meeting of the Association of Land Grant Colleges which will begin on the 13th. It is expected to have the printed program in the hands of members early in October. In accordance with the decision of the executive committee, arrangements have been made to devote the first day to two symposia of a general nature. One of these will have to do with "The Economics of Agronomy" and will be in charge of Mr. E. G. Montgomery of the United States Department of Commerce. The second program will be made up of reports from various members of the Society who have been engaged in agronomic explorations and investigations in other countries.

The second day's program will de bevoted to sectional meetings in soils and field crops. For the soils section, Dr. E. Truog of the University of Wisconsin will act as symposium leader for the general subject of "Soil Colloids" and Dr. K. F. Kellerman of the Bureau of Plant Industry will have charge of the symposium on "Nitrogen Fixation." In the field crop section Professor H. R. Sumner of the University of Kansas will conduct a symposium on "The Legume Problem," this program being prepared to be of particular interest to extension workers. The second symposium on "Plant Physiology and Agronomic Science" will be in charge of Dr. W. L. Burlison of the University of Illinois.

In the evening of the second day, the usual dinner will be held along with the annual business meeting. M. F. Miller, *President.*

MEETING OF THE WESTERN BRANCH OF AMERICAN SOCIETY OF AGRONOMY

The eighth annual conference of the Western Branch of the American Society of Agronomy (formerly Western Agronomic Workers) was held at Laramie, Wyoming, July 21–23, 1924. The conference was attended by about fifty representatives from the states of Wyoming, North Dakota, South Dakota, Nebraska, Kansas, Montana, Colorado, Arizona, Idaho, Utah, Washington, California, and the United States Department of Agriculture. The program was as follows:

Monday, July 21:—Morning Session

1. "Address of Welcome." A. G. Crane, President, University of Wyoming.
2. "Response." F. J. Sievers, President, Western Branch, A. S. A., Washington Experiment Station.
3. "Roll Call." Each man gave his name, position, and a brief statement of his work.

Afternoon Session

1. "Crop Standardization and Registration of Seeds." Paper by A. G. Ogaard, Extension Agronomist, Montana State College. Read by Clyde McKee of Montana.

   This paper detailed the organization and method of growing "certified," "registered," and "approved" seed and emphasized the importance of limiting the number of growers of seed for local consumption.

   Discussion led by Roy Westley, Extension Agronomist, University of Wyoming. Emphasized the importance of making pure seed readily available for local consumption.

2. "Ladino Clover Seed Production and Its Value as a Pasture Crop." R. L. Spangler, Assistant Agronomist, University of Idaho.

   This paper gave in detail the best method worked out for the production of Ladino clover seed and showed the value of this crop as a dairy pasture on land with a high watertable but no alkali.

3. "Some Extension Methods of Field Crops Work." Waldo Kidder, Extension Agronomist, Colorado Agricultural College. This paper emphasized the fact that the Extension Agronomist should not only demonstrate the solution of a problem but by sufficient advertising see that the people actually put it into practice.

   Discussion led by O. S. Fisher, Extension Agronomist, U. S. Department of Agriculture. Emphasized the importance of having only a few projects and having them planned in detail.

4. "Investigation of Livestock Losses on Sweet Clover Pasture." Clyde McKee, Agronomist, Montana State College. This paper pointed out that sweet clover pasture does sometimes bloat cattle but is not nearly as bad as alfalfa in this respect.

   Discussion led by H. W. Hulbert, Agronomist, University of Idaho. Showed value of yellow sweet clover as a pasture crop on the plains area.

Evening Session

1. "Problems in Agronomy as They are Related to the Production of Range and Dairy Livestock." O. S. Fisher, Extension Agronomist, U. S. D. A. This paper gave studies of the production and consumption of hay in the various western states with a view to balancing these two.

2. "The Plan for the Development of a Regional Program of Extension Work in Farm Crops." E. Merritt, Field Agent, Extension Service, U. S. D. A. This paper told of the organization of the Western Extension Service and especially of a new Crops Committee to be added to supply information on crop production, the idea being to adjust farm enterprise rather than increase production.

   Open Discussion. Plans for Tucson Conference.

Tuesday, July 22:—Morning Session

1. Inspection of Wyoming State Experiment Station Farm and Its Work.

2. "A Comparative Study of Hardiness of Wheats." John H. Martin, Agronomist, Western Wheat Investigation, U. S. D. A. This paper reported a rather technical study of winter hardiness in several varieties of western wheats.

3. "Drill Calibration and Its Relation to Stand and Yield of Small Grain." H. W. Hulbert, Agronomist, University of Idaho.

   This paper showed differences in rate of seeding of different varieties in drill and showed the importance of having proper rate for each variety in variety tests.

   Discussion led by M. A. McCall, Agronomist, Cereal Investigation, U. S. D. A.

Afternoon Session

1. "Critical Periods for Irrigation of Wheats." D. W. Robertson, Assistant Agronomist, Colorado Agricultural College. This paper reported a field experiment showing that irrigation water was of most value at about the stooling or jointing period of the wheat plant.

Discussion led by D. W. Pittman, Associate Agronomist, Utah Agricultural College. Brought out other similar results but showed considerable differences with different soil and climatic conditions.

2. "The Prevention of Insect Attack on Stored Grain by Cooper Carbonate Dust." W. W. Mackie, Assistant Professor of Agronomy, University of California.

This paper showed that treating seed grain with copper carbonate dust before storage effectively prevented insect injury.

3. "Predicting Wheat Yields." O. R. Mathews, Assistant in Dry Land Agriculture, U. S. D. A., Newell, South Dakota. This paper showed that in any district there was a very close correlation between the yield of wheat and the available moisture and that the latter might be used in predicting the yield at planting time or later. Open discussion.

4. "National Crossing of Oats." F. A. Coffman, Agronomist Cereal Investigations, U. S. D. A.

This paper showed that some varieties of oats cross rather more readily than had been supposed, which may account for variability of some supposedly pure lines. Open discussion.

5. "Relation of Temperature and Rainfall to Date and Rate of Seeding." A. F. Swanson, Hayes Experiment Station, Kansas. This paper showed that wheat should be seeded before the soil temperature reaches 60 to 65 °F., but not too early if the soil is dry.

6. "Improving the Quality of American-grown Durum Wheats." Paper by J. A. Clark, Agronomist, Western Wheat Investigation, U. S. D. A. Read by J. H. Martin.

This paper told how the quality of American Durum wheats was being improved by crossing rust-resistant varieties such as Pentad, Monad, and Acme, with varieties having good macaroni quality, such as Kubanka and Mindum.

Evening Session

1. "The Nitrogen Problem from the Kansas Point of View." P. L. Gainey, Soil Bacteriologist, Kansas State Agricultural College.

This paper showed that the soils of humid eastern Kansas having a pH value below 6 are losing nitrogen each year, altho legumes tend to rebuild it. The soils of semi-arid western Kansas are not losing nitrogen tho legumes tend to deplete these soils of nitrogen. Laboratory experiments show that pH_6 is a critical point for azotobacter, which offers a possible explanation of these results.

2. "The Soil Nitrate Problem in Colorado." Alvin Kezer, Agronomist, Colorado Agricultural College.

This paper showed that the sugar-beets of the Arkansas Valley are decreasing in yield and quality owing to accumulation of nitrates in soil which seems to be due to excessive nitrogen fixation rather than seepage accumulation of nitrates.

Discussion by W. G. Sackett, Soil Bacteriologist, Colorado Agricultural College. Showed that there were frequent instances of excessive nitrogen fixation in Colorado, the energy probably being furnished to the Azotobacter by the algae in the soil.

General Discussion led by F. J. Sievers, Soils Department, Washington State College.

3. "The Deleterious Effect of Sorghum in the Soil on Succeed[illegible] Crops." By R. S. Hawkins, Agronomist, University of Arizona. Paper read by I. A. Briggs of Arizona.

This paper showed that sorghum draws heavily on the moisture and plant-food in the upper foot of soil and that sorghum should be followed by a deep-feeding crop which receives extra irrigation.

Wednesday, July 23:—Morning Session

1. "The Tillering of Grain as Related to the Yield and Rainfall." Ralph W. Smith, Assistant Agronomist, Dickinson Substation, North Dakota.

This paper showed a close correlation between seasonal tillering and yield but no correlation between tillering and yield of varieties.

2. "Range Losses on Poisonous Plants and Their Control." O. A. Beath, Chemist, University of Wyoming.

Dr. Beath showed several of the poisons he had isolated from the plants of the range of Wyoming with some of their antidotes. The princi[illegible] [illegible]medy seems to be teaching the herders to know all the poison[illegible]s plan[illegible].

3. "Outstanding Weaknesses in Agronomic Investigational Work." F. J. Sievers, Agronomist, Washington State College. Prof. Sievers mentioned that investigational work to date has taken c[illegible] the "wh[illegible] [illegible]d "how" but that the "why" was not given sufficient consideratio[illegible].

On Wednesday afternoon the visitors were taken in c[illegible] on a trip to the Medicine Bow Mountains after which a trout s[illegible] was enjoyed at Centennial, Wyoming. While here Dr. H. I[illegible] Westover gave some interesting sidelights on his travels in South A[illegible], and Professor F. J. Sievers and President A. G. Crane gave interesting concluding remarks.

At the business meeting Wednesday morning it was decided to hold the next meeting at Fort Collins, Colorado, either just before or just after the meeting of the Western Branch of the American Association for the Advancement of Science at Boulder. Clyde McKee of Montana was elected president for th[illegible] ensuing year and D. W. [illegible]man of Utah, secretary, Alvin Kezer of Colorado being automatically the other member of the Executive Committee.

D. W. PITTMAN, *Secretary*.

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THE INJURIOUS AFTER-EFFECTS OF SORGHUM[1]

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INTRODUCTION

The residual, or after-effects of a crop of sorghum, may be considered under two heads: first, the injury of this crop to the plants of some other crop that follows it in a rotation; and second, the effect of sorghum upon the physical condition of the soil.

The first mentioned effect of sorghum is well known and dreaded, and is characteristic of both sacharine and non-sacharine varieties. When sorghum stubble is plowed under and the land planted to small grain, for example, occasionally, but not always, an injurious after-effect is noticed, which is shown in the poor condition of the grain in the early stages of its growth. This effect of sorghum is noticed in nearly every section of the country where this crop is grown, and it has been taught that the effect is due to one or two causes, either the sorghum exhausts the soil of some essential plant food, or it leaves some toxic substance in the soil.

The second named effect, that is the action of the sorghum upon the soil which causes deflocculation, seems to be well known in the semi-arid regions of the West, but it does not seem to be a matter of common knowledge in the more humid sections of the country. This is a point that will be emphasized later on.

The attention of the author was first called to the fact that sorghum would cause a deflocculation of the soil, by an observation of E. F. Chilcott, the superintendent of the dry-land station at Woodward, Oklahoma. In plowing up the plots that had been planted in kaffir, corn and other crops during 1920, Mr. Chilcott noticed that the kaffir

[1]Contribution from the office of Western Irrigation Agriculture, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C. Received for publication September 23, 1924.

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plots were harder than the others, and that the soil turned up in clods. Evidently the soil had been deflocculated, to a certain extent at least, by the growth of the kaffir during the preceding season. Judging from the description of the conditions, it appeared that the trouble might be due to a little "black alkali," or sodium carbonate, in the soil. Sorghum is often considered a vigorous feeder and the first hope in this investigation was to establish this as a fact, and then to build a working hypothesis upon it. If nitrates exist in the soil in that section largely as sodium nitrate ($NaNO_3$), and if sorghum is the vigorous feeder that it is often supposed to be, it was thought that the crop might have withdrawn the nitrate (NO_3) radicle rapidly enough to leave the soil basic with sodium (Na), which ion, by combining with carbon dioxide and water, might have readily become sodium carbonate, or "black alkali."

EXPERIMENTAL WORK

In the first experiment, corn and kaffir plants were placed in competition for plant food, and their relative ability to absorb food when in such competition was measured. Seven large pans, each holding 2500 cc, were prepared, and filled with the nutrient solutions, described in Table 1. The nitrogen in these solutions was derived from sodium nitrate, the potassium from potassium chloride and the phosphorous from sodium phosphate. Perforated aluminum discs, 12 inches in diameter, were floated in each of these pans by means of glass tubes. Each disc was divided by a line into two equal parts, and four-day old corn seedlings were planted upon one-half of the disc, and four-day old kaffir seedlings planted upon the other. This experiment was run in duplicate, and the solutions changed every four days. One set was run for 15 and the other for 19 days. In the lower concentrations, such small amounts of nitrogen were added that neither the corn nor the kaffir would have enough for their use, even though either set managed to get 100 percent of it. To each pan in No. 2, for example, or to the pans of seedlings receiving 2500 cc of a 2 ppm solution, only .005 gram each of N, K and P were added every four days. This amount, especially of nitrogen, was far less than that required by either set of seedlings. The plants in the lower concentrations were, therefore, placed in keen competition for plant food. In the higher concentrations, an abundance of plant food was available for all the plants, so that there was little or no competition.

The plants were grown under a screen, in the open, and at the end of the periods of observation, were taken down, dried, weighed and analyzed for nitrogen only. For convenience, the results are averaged and brought together in Table 1.

TABLE 1.—*Showing comparative feeding power of corn and kaffir seedlings grown in the same nutrient solution.*

No.	Ppm each N, K, and P in nutrient solution	Total dry corn	Weight of crop kaffir	Grams N removed from solution by one gram of dry plant. Corn	Kaffir
1.	None	14.4	2.65	0	0
2.	2	23.3	6.70	.0020	0
3.	5	23.8	4.35	.0046	0
4.	25	20.8	6.00	.0118	.0030
5.	50	22.6	6.30	.0148	.0081
6.	100	19.8	.222	.0193	.0150

The solutions in No. 6 were rather concentrated, the kaffir seemed to suffer from excessive soluble salts more than did the corn, and a very poor crop of kaffir was obtained.

While these results are by no means conclusive, there is no evidence to show that kaffir is a more vigorous feeder than corn when these two plants are placed in competition for plant food.

Another set of determinations, similar to those described above, was now run for 25 days, and the results are brought together in Table 2.

TABLE 2.—*Showing results of a repetition of experiments shown in Table 1 for a longer period.*

No.	Ppm each N, K and P in nutrient solution	Grams N removed from solution by one gram of dry plant. Corn	Kaffir
1.	None	0	0
2.	1	.0036	.0043
3.	5	.0056	.0072
4.	10	.0086	.0100
5.	25	.0254	.0111
6.	50	.0196	.0128

While, in this experiment, the kaffir seemed able to compete with the corn better than it did in the first, there is little evidence that the kaffir plants are more vigorous feeders than the corn. Other observations that are not quoted indicate that the kaffir is not an exceptionally vigorous feeder. It has been observed that plants do vary widely in their ability to obtain food when placed in competition with each other. But as yet no evidence has been obtained that shows that any of the sorghums are better adapted to take care of themselves in the matter of absorbing plant foods than are the other common field crops, corn, oats, barley or wheat.

In the nutrition of plants, nitrogen is frequently the limiting factor. From the results that have so far been obtained, one would not be justified in assuming that the sorghum draws more heavily upon this plant food than do the other crops. The injurious after-effect of sorghum is, therefore, probably not due to the depletion of the soil of

nitrogen. Therefore, in considering the impermeability that often accompanies the toxic effect of the sorghum, one would hardly be justified in assuming that the sorghum draws too heavily upon the NO_3 radicle and thereby leaves the soil basic. There is, probably, no more danger of the formation of "black alkali" from this cause during the growth of sorghum, than during the growth of any of the other crops.

While carrying on the investigations that have just been described, the writer was informed that, in China, sorghum is grown year after year upon the best land, and that no injurious after-effects from the crops had been observed. It was stated that, as fuel is scarce in that country, it is the custom of the Chinese to pull up the stubble and burn it. This suggested that probably the toxic body might be contained in the stubble, and, as this is removed from the soil in this practice, no injurious after-effect would take place. It was because of this suggestion that the work with the stubble that will now, in part, be described, was begun.

Early in November, a quantity of corn, kaffir and cowpea stubbles were pulled up, the soil shaken from the roots and the roots washed and dried. The stubble was then chopped up with a hatchet, about half a gallon measure full of each placed in separate culture pans, and about 2 liters of tap water added to each pan. Perforated aluminum discs were put into these pans and pressed down upon the stubble so that water covered the discs. Wheat seed were then sprinkled upon the discs and allowed to germinate. In the first experiment seven pans were run as follows:

1	Tap water, control					
2 and 3,	"	"	with	corn	stubble	added
4 and 5,	"	"	"	kaffir	"	"
6 and 7,	"	"	"	cowpea	"	"

As it was rather late in the season, and as the nights were cool, the stubbles began fermenting rather slowly, and the wheat seeds sprouted and the seedlings grew for about twelve days without showing any differences. However, when the fermentation began to be noticeable, the plants in Nos. 4 and 5, or those in the kaffir stubble cultures, began to turn yellow at their tips, and in about ten days they all died. The plants in the other culture pans continued to grow. The plants in the corn stubble pans showed a little injury for a few days when the stubble first began to ferment, but they soon recovered and produced better plants than did the control. The plants in the cowpea culture pans were better than any of the others.

In Fig. 1, there is shown a photograph of these pans, taken when the plants were about 30 days old.

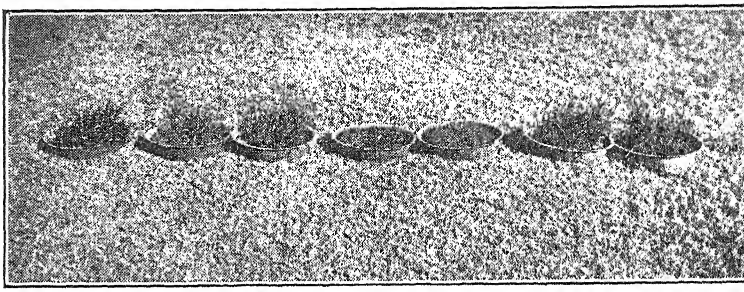

FIG. 1—Showing effect of various stubbles on growth of wheat seedlings. From left to right:

1. Wheat plants growing in tap water.
2 and 3. Plants growing in tap water with corn stubble added
4 and 5. " " " " " " sorghum " "
6 and 7. " " " " " " cowpea " "

After about 30 days, the decomposition in all of the pans seemed to be complete, and no offensive odor could be detected. The healthy plants were now removed from the corn and cowpea cultures, and the dead plants from the kaffir culture pans, and a second crop of wheat was planted upon the aluminum discs of each pan. The culture solutions were not disturbed, except to make them up to their original volume with tap water. This second crop of wheat sprouted and the seedlings grew vigorously in all the pans, and no evidence of any injurious effect of the kaffir stubble was noticed.

This experiment was repeated with kaffir and sorghum stubble many times. The sorghum and kaffir stubbles were taken from different places and compared with corn, cowpea and peanut stubble. When working under like conditions, positive results have always been obtained. It was noticed, however, that occasionally the wheat plants, growing in the sorghum or kaffir stubble, would not die, but would turn yellow and lose most of their leaves. They would then recover and produce fairly good plants. The roots that were first developed would all rot off, but a new root system would soon be developed which seemed to be perfectly normal.

As a result of this observation, some corn, kaffir and cowpea stubbles were placed in pans, wetted and allowed to decompose without planting any wheat upon the aluminum discs. When the decomposition was over, the solutions were poured from the stubbles into other culture pans, the stubbles discarded and wheat seeds planted upon the aluminum discs floating in the solutions. All of these culture pans produced good plants. It appeared that a toxic body was de-

veloped during the decomposition of the sorghum stubble, and that this toxic body was, shortly, either volatilized or was itself decomposed into non-toxic compounds.

It appears that the development of this toxic body depends largely upon temperature. When culture pans are placed near a furnace, so that they are always warm, the decomposition of the stubble can be completed, and a good nutrient solution can be produced from finely chopped sorghum stubble in three or four weeks.

As before mentioned, in the first stages of its decomposition, corn stubble, and even cowpea stubble, develops products that are slightly injurious to wheat seedlings. This effect soon passes off, and the wheat seedlings, grown in these cultures, develop better than the control. As the cowpea is a legume, and as the plant runs high in nitrogen, it might be expected that wheat plants, when grown in a culture containing the chopped-up cowpea stubble, would develop better than the control. This is usually the case. However, it was a little surprising to note that after corn stubble had gone through its decomposition, the wheat plants growing in the cultures began to turn green and to show that they were getting a supply of nitrogen. Plants grown under such conditions usually live longer and grow larger than plants grown in tap water. Upon two occasions plants from a set of culture pans were analyzed for nitrogen, and the following are the results of one set of analyses:

Analyses of wheat seedlings grown in	Nitrogen in 100 plants.
1. Tap water, control	.1316 gms.
2. " " with corn stubble	.2520 "
3. " " " kaffir stubble	.1355 "

These analyses show the nitrogen content of wheat seedlings that were grown in the first crop. The kaffir stubble completely stopped the absorption of nitrogen by the seedlings, but evidently the plants that grew in the corn stubble cultures got some nitrogen from the decomposing stubble. These plants contained nearly twice as much nitrogen as did the control plants.

This phenomenon seems to be certain to occur, and it also seems to be of considerable importance. Experience has shown it to be best, both in humid and semi-arid regions, to follow corn with wheat. There may be other reasons for the practice, such as the good seed bed left by the corn, but the mere fact that the corn stubble gives up its nitrogen to the young wheat plants at this stage of their growth may be a sufficient reason to justify the agricultural practice.

Another fact with reference to the stored up nitrogen in corn and sorghum stubble was demonstrated. If the culture pans of corn stubble are fermented for months, or until the decomposition is over, the sorghum stubble will give up its nitrogen to wheat seedlings just as readily as the corn stubble does. The plants grown in the sorghum stubble show just as much increase in the nitrogen content, and just as much improvement in the size and color of the plants as do those grown in corn cultures.

DISCUSSION OF RESULTS

It appears that a toxic compound is developed in sorghum stubble during the process of decomposition. It is an easy matter to tell by the odor just when the toxic substance in the culture pan is formed, and, furthermore, it is easy to tell by the change in smell, just when the toxic body has been volatilized or decomposed.

Several times the sorghum mixtures were brought to the proper stage of decomposition and the mixtures poured into a large retort and the volatile products distilled off. From a mixture that is toxic to wheat seedlings, a poisonous compound can be distilled off, which will kill wheat plants within a few hours. The identity of this poisonous compound, or of the compounds in these toxic distillates, has not been determined. From young sorghum plants, especially in the second growth that comes up from the stubble in the fall, hydrocyanic acid has often been isolated. This acid, or its compounds, sometimes is present in such large amounts in the fresh plants that cattle are killed by eating them. Hydrocyanic acid is volatile, it is easily decomposed, and it is also extremely toxic to plants. It may be that the toxic after-effect of sorghum is due to the formation of hydrocyanic acid in the decomposing stubble. However, this has not been determined.

The results that have been discussed so far have been those that have been obtained from water cultures. Sand and soil cultures, in pots and in small beds upon green house benches, have also been carried on. In general, the results with sand and soil cultures are similar to those obtained with water cultures, that is, all the results point toward the formation of a toxic compound during the first stages of the decomposition of sorghum stubble, and its later decomposition or volatilization.

When sorghum stubble is mixed with sand, put into pots or into small plats upon green house benches, planted to wheat, oats or barley, and free drainage allowed, no injurious effect from sorghum stubble has ever been noticed. However, when a heavier soil is taken and no drainage from the pots is allowed, the effect of

the sorghum is quite evident. Wheat, for example, comes up nicely in such soil cultures, grows for probably two weeks, then turns yellow and stops growing for a while. After a week or ten days it usually recovers and in the end generally produces fairly good plants.

This peculiarity of the toxic effect of sorghum is noticed in nearly all crops in the field. They suffer for a while and then recover. Cotton often fails to set an early crop during the time that it is showing injury, but later it usually recovers and sets a normal crop.

The after-effect of sorghum is a serious problem in the west, especially in Arizona. The grain sorghums fit into many rotations. They would be more extensively grown if they did not have such an unfavorable reputation. The injurious effect of sorghum seems more pronounced here than in the East or Southeast. The reasons for this are apparently evident. From the results here described, it appears that the effect is short-lived. It is the general experience that the effect is shown more often upon small grain than upon other crops. The probable reason for this is that the sorghum stubble is plowed under in the fall and grain planted immediately afterwards. The grain is, therefore, subjected to and injured by the toxic compound before it has had time to volatilize. In colder climates, there is no fall crop and no planting is done before late in the next season, and the injurious after-effect would probably not often be noticed under such conditions. In the humid regions of the South, where there is just enough frost to kill the sorghum, where the soil does not freeze, and where there is an abundance of rain during the winter, one would also not expect to find the injurious after-effect nearly so common. In the Southwest, often there is not enough cold to kill the stubble, so that if it has sufficient water, it may live through the winter and start up in the spring. When such stubble is plowed under in the spring, and the land is planted to corn or cotton, the injurious after-effect is likely to be noticed. Even when the crop of sorghum is cut during the late summer, and the soil is left to dry out, the stubble does not decompose until it is plowed under in the spring. In this case, it would be expected that the injurious effect would be manifested upon the spring or summer crop. From the results of the experiments herein described, it would seem that the toxic effect might be more pronounced upon heavy soils or upon soils with heavy subsoils and upon soils with poor drainage, than upon sandy soils or soils with good drainage.

A possible remedy which suggests itself is the wetting and plowing under of the stubble in the fall, and allowing the decomposition to

come to an end before planting any crop. In a rotation it might be advisable to arrange to follow sorghum with some summer crop. At any rate, it certainly seems advisable to plow under the stubble as soon as possible after the crop is harvested and to wait as long as possible before planting another crop.

RELATION OF TOXIC EFFECT TO IMPERMEABILITY OF THE SOIL

So far, only the toxic after-effect of the sorghum has been dealt with. The other factor, that of impermeability of the soil, will now briefly be considered. In Arizona, the deflocculating effect of sorghum upon the soil has often been observed. There is no doubt that it often takes place after a heavy crop, but it is doubtful if the effect is often noticed after a light crop. The toxicity of the stubble and the impermeability that is induced in the soil are certainly associated. The main object of this paper is to show the correlation between these two phenomena.

PROBABLE CAUSE OF SOIL IMPERMEABILITY

In working upon the deflocculated and impermeable soils of this region, one soon becomes convinced that practically every case of deflocculation is brought about by the presence of "black alkali," or sodium carbonate, in the soil. It seems safe to say that the deflocculation that is noticed after a heavy crop of sorghum may also be traced to the same cause, that is, to the presence of black alkali in the soil.

Deflocculation is not noticed after all cases of toxicity, and deflocculation will probably not be produced except in soils which, at that particular time, either contain a little black alkali, or are near to a state of alkalinity. Deflocculation will probably not take place upon acid soils, such as are found in the South, or upon soils that contain relatively high proportions of gypsum. In some sections, soils will get hard after many crops; hence, deflocculation should not necessarily be attributed to sorghum in such cases. Deflocculation does not seem to be a disease, but rather a symptom.

The sodium colloid, or the sodium zeolite, is undoubtedly the cause of the trouble in these impermeable soils. This compound, which is probably a combination of sodium and silica, causes the dispersion of soil particles, which is called deflocculation. This deflocculation may be overcome in several ways, particularly by the addition of a soluble lime salt, such as gypsum. The calcium in gypsum displaces the sodium in the zeolite, with the formation of a calcium zeolite and sodium sulphate. The calcium colloid, or calcium zeolite, is not dis-

persed and brings the soil into a state which is called flocculation. Hence, soils which contain an excess of sodium are dispersed and impermeable to water, while soils with an excess of calcium are flocculated and usually take water readily. The state of flocculation, or of deflocculation, often depends upon a very slight excess of either calcium or sodium in solution. A small amount of calcium, for example, is sufficient to flocculate a dispersed soil, if such soil is very near to the state of alkalinity. This same characteristic is true of sodium. A very small amount of sodium will sometimes cause a soil to disperse or to become impermeable.

A great deal of evidence is on hand and other evidence is accumulating which goes to show that in the drying out of dispersed soils, as the proportion of the moisture is decreased and as the dry soil is approached, a change in the composition of the zeolite takes place. Calcium is gradually replaced in the zeolite by sodium, the calcium taking the form of calcium carbonate, while the sodium unites with the silica and forms a sodium zeolite. The sodium zeolite is the dispersing agent, so that in a perfectly dry, black alkali soil there may be very little calcium zeolite and a great deal of sodium zeolite. Dry soils are, therefore, likely to be highly dispersed.

Practically all arid soils, and soils that contain black alkali, are calcareous. An abundance of calcium carbonate is always present, even in the most impervious soils. Dispersion, or deflocculation, under Southwest conditions, does not usually take place when there is a considerable amount of calcium in solution, but, although these soils may contain 5 percent or more of calcium carbonate, this salt, because of its low solubility, is inert as far as dispersion is concerned. But calcium carbonate, in the presence of carbon dioxide, goes into solution much more readily and forms calcium bicarbonate.

If calcium bicarbonate is present in the soil solution, a different effect is produced. A solution of calcium bicarbonate will flocculate a soil just as readily as the equivalent concentration of calcium sulphate. A solution of 300 ppm of calcium as calcium bicarbonate may easily be obtained by bubbling carbon dioxide through distilled water containing calcium carbonate. This solution will flocculate a highly dispersed soil just as readily as a solution of 300 ppm calcium as calcium sulphate.

If distilled water is percolated through a deflocculated soil which contains both sodium carbonate and calcium carbonate, only a small amount of water will usually pass through, as the soil soon becomes sticky and water will not penetrate. If, however, carbon dioxide is first bubbled through the water before it is applied to the soil, the

water will penetrate the soil quite rapidly and flocculate it. The percolations of such a soil may now be carried on indefinitely, provided a little carbon dioxide is kept in the distilled water. When carbon dioxide gas is introduced into water, it dissolves some calcium carbonate, with the formation of calcium bicarbonate, $Ca(HCO_3)_2$. The calcium in the calcium bicarbonate now displaces the sodium in the dispersed colloids, a calcium colloid is formed, and the soil is flocculated.

In practical agriculture the soil atmosphere is always very high in carbon dioxide. This is brought about by the action of the soil flora upon the organic matter in the soil. The production of carbon dioxide is stimulated when cover crops are plowed under or manure applied to soils. Material for the bacteria to work upon is supplied in this way. The practical effect of organic matter upon black alkali soils is well known.

Recently[3] the writer has endeavored to show that the plant uses carbon dioxide in order to maintain equilibrium in its tissues, and that carbon dioxide is necessary in maintaining equilibrium in the soil solution during the absorption of nutrient material by the plant. The rôle of carbon dioxide may be carried still further. Under arid conditions, where the soil is calcareous and slightly alkaline, carbon dioxide is probably the one agent that prevents such soils from becoming practically impermeable to water. Carbon dioxide may be looked upon as a check, a safety valve, that tends to keep the equilibrium pushed back,—it tends to prevent the formation of sodium colloids.

As might be expected, the effect of carbon dioxide is of a temporary nature. If water is added to a highly dispersed soil, it may be thoroughly flocculated with CO_2, and water will pass through such a soil freely. All of the sodium in the colloid is replaced by calcium. If this soil, with its solution, is now dried out, it will return to its original dispersed condition, that is, it will again be deflocculated, and water will not readily penetrate it. The drying out process drives off some carbon dioxide. If the clear solution from a soil that has been flocculated with CO_2 is boiled for a while, made up to volume, and again added to the soil, the soil will again become dispersed.

A continuous supply of carbon dioxide, together with a certain amount of moisture, seems to be necessary in maintaining an equilibrium that will prevent the formation of an excess of sodium colloids. This is a very important point in the consideration of soil permeability. Anything that tends to check bacterial action, even temporarily, is apt to interfere with the penetration of water.

[3]See Jour. Agr. Res. 24:303–311, 1923.

If a poisonous compound is formed during the decomposition of sorghum stubble, and if this compound is sufficiently toxic to kill high forms of plant life, such as wheat, it is certainly reasonable to assume that such a strong toxin may kill off the lower forms of life, or the bacterial flora of the soil. The soil, after a heavy crop of sorghum, feels sterile and "dead." It feels like a soil that has been burned.

In view of these discussions, the following explanation of the injurious after-effects of sorghum is offered. Suppose after a crop, a poison is temporarily formed in the soil during the decomposition of the stubble. The soil is probably already slightly alkaline and would probably be deflocculated naturally if it were not for the soil organisms that are continually generating carbon dioxide. The CO_2 is probably maintaining the equilibrium, with a slight balance in favor of the calcium colloid. Suppose that the soil organisms are all killed off by the toxic body in the sorghum stubble. The evolution of CO_2 will temporarily cease, and another equilibrium will be established with a probable slight excess of the sodium colloid. The soil will now become more or less deflocculated, depending upon the number of bacteria killed, the percent of organic matter, the percent of moisture in the soil, and probably upon other conditions.

The deflocculation caused by a crop of sorghum is usually temporary,—it disappears within a few months, and this fact also points to the action of carbon dioxide. There seems to be nothing "fundamentally wrong" with a sorghum soil, else it would not recover in the course of a few weeks. Soils do not ordinarily change so rapidly with respect to their fertility. There is a reason for this rapid change, and the presence or absence of carbon dioxide explains it fairly satisfactorily.

SUMMARY

The results of these experiments indicate:

First, that the injurious after-effect of sorghum is due to the presence of a toxic body formed during the decomposition of the stubble.

Second, that this toxic body is shortly volatilized or decomposed.

Third, that during the decomposition of the stubble, and while the toxic body is still in the soil, the flora that generates the carbon dioxide is, to a large extent, killed off.

Fourth, that with the cessation of the evolution of carbon dioxide, a new equilibrium is established in the soil, in which the sodium zeolite exists in excess over the calcium salt. This causes a deflocculation of the soil.

SOIL CONDITIONS WHICH PROMOTE NITROGEN FIXATION[1]

N. E. WINTERS[2]

INTRODUCTION

In many of the older cultivated soils of the United States, nitrogen is the limiting element in crop production and must be supplied before other fertilizer materials give profitable returns. Results of investigations of soil fertility indicate that the proper use of clovers and other legumes in rotation and the systematic use of liming materials is a more economical method of solving a large part of the nitrogen problem for general field crops than to depend solely on commercial forms of nitrogen.

The assimilation of free nitrogen by soil organisms working independently of leguminous plants, is often not considered in calculating the nitrogen balance in the soil; but it is the opinion of some investigators that this form of bacterial activity plays a large part in keeping up soil productivity.

REVIEW OF LITERATURE

In 1885, Berthelot (4)[3] demonstrated that soil organisms assimilate gaseous nitrogen. He exposed sterilized and unsterilized soils poor in nitrogen to air in large closed flasks for several months. The unsterilized soils gained in nitrogen, but the sterilized soils did not. In 1893, Winogradski (34) started a search for the actual organism and finally isolated an anaerobic form which he called *Clostridium pastorianum*. In 1901, Beijerinck (3) isolated two aerobic forms to which he gave the generic name of *Azotobacter*, and up to the present time the Azotobacter group seems to be the most important of all the nitrogen fixers. In 1903-04, Lipman (21) described three more species of Azotobacter. Many soil organisms, including bacteria, yeasts, molds, and fungi, have been credited with nitrogen fixing power (22) (9). Although the Azotobacter group is considered to be the most important, nitrogen assimilation is faster in the presence of other forms than with pure culture (20). Kossowitsch (19) found that certain algae and Azotobacter can work together symbiotically. He

[1]A thesis submitted to the Faculty of the Graduate School of Cornell University in partial fulfilment of the requirements for the degree of doctor of philosophy. Received for publication August 16, 1924.

[2]It was the object of this investigation to shed more light, if possible, on optimum soil conditions which permit maximum activity of the nitrogen fixing organisms.

[3]Reference by number is to "Literature Cited," page 715.

concluded that the algae furnish carbohydrates as a source of energy for the Azotobacter, and the latter fixes nitrogen for both. This was confirmed by Bouilhac (5).

In 1905, Jamieson (16) claimed that all green plants possess the power of fixing nitrogen, and in 1922 Lipman and Taylor (23) published the statement that in a series of experiments they found that wheat plants fix nitrogen from the air.

Free nitrogen-fixing organisms are found in most soils (24) (15). It is often very difficult to isolate any members of the Azotobacter group in soils deficient in $CaCO_3$ (32) (7). In fact, Christensen (7) has suggested that the Azotobacter be used as an index for determining the need of lime in the soil. Ashby (1) found the relative distribution of Azotobacter and Clostridium in the Rothamsted soils to depend on the limestone content of the soil. Where no limestone was found only *Clostridium pastorianum* was present.

Yamagata (35) found Azotobacter in 100 soils out of 300 in twelve districts in Japan. Ten to 15% of the acid soils, 30% to 48% of the slightly acid and 59% to 66% of the neutral or slightly alkaline soils of Japan contain Azotobacter. Yamagata and Wilson in the summer of 1922 (35), working with pure cultures, found that *Azotobacter chroococcum* made the most vigorous growth at a pH value of 6.8; Beijerincki sets this value at 6.6, and A. Vinelandii at 7, or the neutral point.

It is generally agreed by bacteriologists that 25 pounds of nitrogen or more are fixed in the surface soil per acre per year by free fixation. At Rothamsted, in the Geescroft Field (12) which was allowed to run wild for a period of twenty years, there was an average gain in the top nine inches of soil of over 44 pounds of nitrogen per acre per year. This soil contains about 16% $CaCO_3$ and bore a natural herbage of only 43% leguminous plants. During the same period, the Broadbalk field gained about 98 pounds of nitrogen per acre per annum. The latter soil contains 3.3% $CaCO_3$ and 25% of the natural herbage was legumes. These field results indicate that probably forty percent or more of the gain in nitrogen where the legumes were growing was due to free fixation.

EXPERIMENTAL WORK

METHODS AND PROCEDURE

Two types of soil were used, Volusia silt loam, which is typical of most of the hill lands of southern New York, and Dunkirk clay loam of glacial lake deposit. Agriculturally, the Dunkirk is a more productive soil than the Volusia. Chemically, they are similar, except that the Volusia is much lower in calcium and sulphur. The Volusia has a higher lime requirement according to the Veitch method.

When first brought in from the field the soil was rubbed through a 2 mm. sieve, and stored in five gallon glass-stoppered bottles during the course of the experiments. The Dunkirk soil contained 16% moisture, and the Volusia 11%, when bottled.

Powdered materials added to cultures were thoroughly mixed with the soil before water was added. Once each week during the incubation, the soil cultures were thoroughly stirred and aerated and moisture content renewed. The experiments were all conducted under laboratory conditions at room temperature. Care was taken that none of the cultures were affected by the sun's rays through windows and that none were too close to radiators.

Determination of Nitrogen

The Kjeldahl method was used for the determinations of total nitrogen. The colorimetric method with phenoldisulphonic acid was used for determining nitrates. In making total nitrogen determinations, if duplicate samples failed to check within .3 cc N/10 NaOH, the analysis was repeated. The results given are the averages of duplicate samples in each case. All tests except one were carried in quadruplicate cultures.

Nitrates were determined in several of the experiments in order to check up the effect of conditions favoring fixation on nitrate accumulation.

Variability and Probability

Bessel's method[4] was used to determine the standard deviation and coefficient of variability. Bessel's modified method and Student's[5] method were both used in determining the probability of the results.

Size of Containers

In order to determine the best size of vessels to use for incubation, large open pans containing 500 grams of soil were compared with covered tumblers containing 100 grams of soil. Volusia silt loam soil was used, 25% moisture was maintained as nearly as possible and .5% $CaCO_3$ was added. The incubation period was from November 17, 1920, to December 29, 1920, six weeks. The soil in the large pans was cultivated and water added to initial weight every 48 hours. The soil in the covered tumblers was cultivated once each week during the incubation period, and it was necessary to add water only once each week to keep up the desired percentage of moisture.

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[4]WOOD and STRATTON, Interpretation of experimental results. *In* Journ. Agr. Sci., 3:417–458.

[5]Student, The probable error of a mean. *In* Biometrika, 6:1–25. 1908.

It was found that more nitrogen was fixed in the large pans than in the covered tumblers; but the variability of the results was much larger. The coefficient of variability of a single observation with the large open pans was 29.7% against 8.8% for the covered tumblers. This was due, no doubt, to the possibility of maintaining more uniform conditions in the tumblers. The large pans also required much more time and attention during the incubation period. Hence, covered tumblers containing 100 grams soil were used throughout the following experiments.

Effect of Pressure

One hundred gram samples of Dunkirk clay loam soil were incubated in covered tumblers two and four weeks, both under pressure and without pressure. Two percent mannite and .5% $CaCO_3$ were added to each culture, and the moisture content was maintained at 25%. The incubation period started December 28, 1920, and cultures were harvested Jan. 13 and Jan. 27. Over one-half the cultures pressure was maintained at 23 to 27 pounds per square inch during the incubation period. Soil was analyzed at the beginning of the experiment as a check on the progress of the fixation process. The results showed no significant gain for pressure.

Cultures of Volusia silt loam soil were incubated for two weeks under atmospheric pressure in comparison with others under 30 pounds pressure. Thirty percent moisture and .1% $CaCO_3$ were added to each culture. Increasing the pressure did not increase nitrogen fixation.

The effect of pressure varying from 23 to 37 pounds in comparison with atmospheric pressure on nitrate accumulation was also tested without consistent positive results for pressure. As a result of these preliminary experiments, the use of increased pressure was abandoned as a means of hastening the experimental work.

RESULTS OF EXPERIMENTS

In this experimental work, there was tested the effect of varying amounts of liming materials, gypsum, calcium silicate, fertilizer materials and several other factors which may influence nitrogen fixation in the soil.

Inoculation with Azotobacter

As shown by the data reported in Table 1, heavy inoculations with pure cultures of Azotobacter did not stimulate nitrogen fixation in the Volusia soil, which was the one with the higher lime requirement. It seems that, when soil conditions are made favorable for the nitrogen-fixing bacteria to work, inoculation is unnecessary. The

writer was able to isolate Azotobacter from both Volusia and Dunkirk soils two weeks after limestone had been added.

TABLE 1.—*Effect of inoculation upon nitrogen fixation.*

Test no.	Treatment	Mg. N in 10 g. soil	Average	Average increase
1	Dried at 100° C as check	17.64		
2	" " " " "	17.36	17.50	
3	No inoculation	20.44		
4	" "	20.16		
5	" "	20.30		
6	" "	20.02	20.23	2.73
7	Inoculated with Azotobacter	20.30		
8	" " "	20.44		
9	" " "	20.16		
10	" " "	20.44	20.33	2.83

Light versus Heavy Applications of Limestone

On Feb. 11, 1922, an experiment was started to determine the best amount of limestone to use with Volusia silt loam for maximum nitrogen fixation during three-weeks and six-weeks periods. The soil in all the tumblers was kept at a moisture content of 25% and 1% mannite

TABLE 2.—*Effects of light and heavy applications of limestone on nitrogen fixation, Volusia soil.*

Test no.	Treatment	Mg. N in 10 g. soil		Average		Average increase over check	
		3 wks.	6 wks.	3 wks.	6 wks.	3 wks.	6 wks.
1	Check dried at 100° C	18.34	18.62	18.49			
2	" " "	18.48	18.48				
3	No limestone	18.76	18.62				
4		18.90	18.90				
5		18.76	18.76				
6		18.72	18.76	18.76	18.76	.26	.26
7	.1% limestone	20.30	21.08				
8		20.44	21.22				
9		20.44	20.94				
10		20.30	21.36	20.37	21.15	1.88	2.66
11	.2% limestone	20.72	21.36				
12		20.44	21.50				
13		20.44	21.36				
14		20.72	21.50	20.50	21.43	2.09	2.94
15	.5% limestone	20.30	21.36				
16		20.58	21.22				
17		20.44	21.50				
18		20.44	21.08	20.44	21.29	1.95	2.80
19	1% limestone	20.72	21.08				
20		20.44	21.36				
21		20.44	21.50				
22		20.72	20.94	20.58	21.22	2.09	2.73
23	2% limestone	20.30	21.50				
24		20.58	21.22				
25		20.44	21.36				
26		20.44	21.36	20.44	21.36	1.95	2.87
27	3% limestone	20.44	21.08				
28		20.44	21.36				
29		20.58	21.50				
30		20.30	20.94	20.44	21.22	1.95	2.73

was added to all the soil as a source of energy for the organisms. Two cultures of soil were dried at 100°C, to stop all bacterial activity on the same day the experiment was started. The amount of precipitated $CaCO_3$ used varied from none, in cultures 3–6, to 3% in cultures 27–30. Calculated upon the acre basis .1% is equal to one ton per acre and 3% to thirty tons per acre.

The results shown in Table 2 indicate clearly that .2% $CaCO_3$ in Volusia silt loam soil promoted fixation as much as did any larger amount, and, under the conditions of this experiment, .2% was more beneficial than .1%. It is questionable, however, whether in practice it is advisable to use as heavy an application of lime as .2%. The probability of the results were tested by Student's method and by the modified Bessel's method as indicated. The former shows that the odds are 99:1 that .1% $CaCO_3$ promotes nitrogen fixation and 118:1 that .2% is better than .1%. The latter, that .2% is better than .1% by odds of 1000:1.

As Dunkirk clay loam shows a much lower lime requirement than Volusia silt loam, an experiment was conducted in an attempt to determine the amount of limestone needed for maximum fixation in this soil type. Mannite was added as with the Volusia soil and 30% moisture was maintained. Varying amounts of limestone, from .1% to .4% were used in comparison with checks with results as indicated in Table 3.

TABLE 3.—*Influence of limestone on nitrogen fixation, Dunkirk soil.*

Test no.	Treatment	Mg. N. in 10 g. soil	Average	Average increase over check
1	Check, dried at 100° C	14.42		
2	" " " "	14.42	14.42	
3	No limestone	14.56		
4		14.70		
5		15.12		
6		15.12	14.88	.46
7	.1% limestone	17.36		
8		17.22		
9		17.50		
10		17.84	17.43	3.01
11	.2% limestone	17.64		
12		17.36		
13		17.64		
14		17.78	17.60	3.18
15	.3% limestone	17.78		
16		17.64		
17		17.78		
18		17.36	17.64	3.22
19	.4% limestone	17.36		
20		17.22		
21		17.36		
22		17.50	17.36	2.94

Again maximum fixation was obtained with .2% $CaCO_3$. With the Dunkirk soil .2% $CaCO_3$ did not give so large increase in total nitrogen over the .1% as in the Volusia silt loam.

Applying Student's method for determining probable error to these results, it shows odds of 141:1 that .2% is better than .1%. If Bissel's modified method is used the odds are 64:1 that .2% is better than .1%.

Effect of Pea Vines on the Amount of Limestone for Maximum Nitrogen Fixation

Finely ground pea vines were thoroughly mixed with Volusia silt loam soil at the rate of ten tons per acre, and applications of precipitated $CaCO_3$ were made at rates varying from .1% to .5%. Incubation was started March 25 and the cultures were harvested April 15. The results are shown in Table 4.

TABLE 4.—*Influence of limestone on nitrogen fixation, Volusia soil with added pea vines.*

Test no.	Treatment	Mg. N. in 10 g. soil	Average	Average increase over check
1	Check, dried at 100° C	17.36		
2	" " " "	17.64	17.5	
3	.1% limestone	20.30		
4		20.16		
5		20.02		
6		19.98	20.12	2.62
7	.2% limestone	20.44		
8		20.30		
9		20.30		
10		20.44	20.37	2.87
11	.3% limestone	20.44		
12		20.30		
13		20.44		
14		20.30	20.37	2.87
15	.4% limestone	20.30		
16		20.16		
17		20.30		
18		20.16	20.23	2.73
19	.5% limestone	20.16		
20		20.16		
21		20.02		
22		20.02	20.09	2.59

One-tenth percent limestone, or one ton per acre, gave a large increase in nitrogen fixation, and a two-ton application gave still larger increases. Larger quantities gave no significant additional gains, although no decreases resulted from heavier applications. This agrees with results secured by Mockridge (26). According to Koch (18), too much burned lime (CaO) may easily be applied for the nitrogen fixing bacteria.

Student's method of determining probability of results shows odds of 42:1 that .2% $CaCO_3$ is better than .1%, and Bessel's modified method shows odds of about 1189:1 that .2% is better than .1% in promoting nitrogen fixation in the presence of peavines.

At the time of making total nitrogen determinations, each culture was analyzed for nitrates present, in order to determine the relation between rapid nitrogen fixation and nitrate accumulation.

It was found, in every culture where conditions were made favorable for rapid nitrogen fixation, that there was a decided decrease in nitrates during the incubation. It is thought that many organisms capable of destroying fresh organic matter use nitrates and synthesize them into organic forms of nitrogen. The decrease obtained is shown in Table 5.

TABLE 5.—*Influence of limestone on nitrate accumulation in the presence of peavines, twenty-one days incubation.*

Treatment	Mg. NO_3 in 100 g. soil
Checks	47
.1% limestone	4
.2% "	9
.3% "	16
.4% "	19
.5% "	21

Effect of Varying the Quantities of Pea Vines on Nitrogen Fixation

Many cow-peas are grown in the south-eastern states of the United States. It is of considerable economic interest to know the effect of

TABLE 6.—*Effect of ground cow pea vines on nitrogen fixation.*

Test no.	Treatment	Mg. N added in pea vines to 10 g. soil	Corrected for pea vines Mg. N in 10 g. soil 3 wks.	6 wks.	Average 3 wks.	6 wks.	Average increase over check 3 wks.	6 wks.
1	Check, dried 100° C	0	18.48	18.34				
2			18.20	18.20	18.27			
3	No pea vines	0	20.72	21.84				
4			20.86	21.84				
5			20.86	21.98				
6			20.72	21.98	20.79	21.85	2.52	3.58
7	.1% pea vines	.2	20.66	21.92				
8			20.94	21.78				
9			20.94	21.92				
10			20.80	21.92	20.84	21.89	2.57	3.62
11	.3% pea vines	.6	20.54	21.66				
12			20.68	21.80				
13			20.82	21.94				
14			20.82	21.94	20.72	21.84	2.45	3.57
15	.5% pea vines	1.0	20.70	23.36				
16			20.84	23.22				
17			20.84	23.22				
18			20.70	23.08	20.77	23.22	2.50	4.95
19	1.% pea vines	2.0	20.68	23.20				
20			20.68	23.34				
21			20.54	23.20				
22			20.82	23.06	20.68	23.20	2.41	4.93
23	1.5% pea vines	3.0	21.78	23.18				
24			21.92	23.32				
25			21.02	23.18				
26			21.78	23.32	21.85	23.25	3.58	4.98

this form of organic matter on nitrogen fixation. Accordingly, cow pea vines in amounts ranging from one to fifteen tons per acre were added to soil and the increase of nitrogen determined at the end of three and six weeks. Table 6 shows the results. After making due allowance for the nitrogen added in the pea vines, the cultures receiving .5% or more of pea vines show considerable increase in nitrogen fixation over the cultures with mannite alone. .5%, or five tons per acre, showed as much increase over a six weeks' period as any larger applications did.

During this period of incubation the nitrates (38 ppm) which were present at the beginning of the experiment entirely disappeared from those cultures receiving pea vines. These findings confirm those recorded in Table 5.

Composted Organic Materials as a Source of Energy in Nitrogen Fixation

The quality of organic matter as the source of energy for nitrogen fixation seems to be a very important factor. Richards (28) found that the diet of animals influenced the value of their feces in its effect on nitrogen fixation. Feces from horses fed on oats gave the highest results, and the feces of cows fed on grass gave the lowest results.

TABLE 7.—*Comparison of effects of fresh and rotted oat straw, pea vines and horse manure on nitrogen fixation.*

Treatment	Mg. N. added in organic matter	Corrected for organic matter Mg. N. in 10 g. soil		Average		Average increase over check		Average increase over no organic matter	
		3 wks.	6 wks.	3 wks.	6 wks.	3 wks.	6 wks.	3 wks.	6 wks.
Check		18.48	18.48	18.48	18.48				
No organic matter		19.74	20.44						
		20.02	20.72	19.88	20.58	1.4	2.10		
Fresh oat straw	.7	19.74	21.14						
		19.88	20.86						
		20.02	21.00	19.88	21.00	1.4	2.52	0.0	0.42
Rotted oat straw	.8	21.46	22.30						
		21.84	22.58						
		21.18	22.44	21.46	22.44	2.96	3.96	1.56	1.86
Dry pea vines	2.0	21.66	21.66						
		21.38	21.80						
		21.10	21.52	21.38	21.66	2.90	3.18	1.50	1.08
Rotted pea vines	2.5	21.58	22.56						
		21.30	22.28						
		21.02	22.42	21.30	22.42	2.82	3.94	1.42	1.84
Fresh horse manure	.5	21.76	22.46						
		21.48	22.60						
		21.20	22.32	21.48	22.46	3.00	3.98	1.60	1.88
Rotted horse manure	.6	22.92	24.32						
		23.20	24.60						
		23.06	24.04	23.06	24.32	4.58	5.84	3.18	3.74

In this connection, the results shown in Table 7 are very interesting. Composting the oat straw caused a rapid nitrogen fixation during the first six weeks. Well-rotted stable manure promoted the work of the nitrogen-fixing bacteria much better than did fresh manure, although the fresh manure gave as good results as either the rotted pea vines or rotted oat straw. Rotting the pea vines increased the fixation during the second three weeks. These results agree with those of Lohnis and Green (25), in that composting the substances increases nitrogen fixation. However, these investigators found fresh straw more valuable than fresh stable manure.

Comparison of Limestone, Burned Lime and Gypsum on Nitrogen Fixation

In an effort to determine the best form of calcium to use in promoting nitrogen fixation, equal quantities were supplied in the form of $CaCO_3$, CaO and $CaSO_4.2H_2O$. Mannite was used as a source of energy. Incubation was started April 10 and the cultures were harvested May 2. Table 8 shows the results.

TABLE 8.—*Comparison of $CaCO_3$, CaO and $CaSO_4$ in their effect on nitrogen fixation.*

Test no.	Treatment	Mg. N in 10 g. soil	Average	Average increase over check
1	Check, dried at 100° C	18.76		
2		18.76	18.76	
3	No amendment	19.32		
4		19.04		
5		19.18		
6		19.18	19.18	.42
7	.2% $CaCO_3$	20.44		
8		20.58		
9		20.30		
10		20.44	20.44	1.68
11	.112% CaO	20.58		
12		20.44		
13		20.30		
14		20.16	20.37	1.61
15	.27% $CaSO_4$	19.46		
16		19.32		
17		19.04		
18		19.18	19.25	.49

Where no amendment was used there was an average increase of .42 milligrams of nitrogen in each 100 grams of soil.

$CaCO_3$ and CaO had practically the same effect in increasing nitrogen fixation. The odds in their favor are over 99 to 1. The $CaSO_4$ had no significant effect. The odds are only 3:1 that it is any better than no treatment. Probably, this soil contained enough sulphur to supply the needs of the nitrogen-fixers. Christensen (6) found that Azotobacter cannot use the calcium in $CaSO_4.2H_2O$

Comparison of Limestone and Calcium Silicate

On April 27, 1922, a series of cultures was started, in which limestone was compared with varying amounts of $CaSiO_3$ on nitrogen fixation. Volusia silt loam was used. Time of incubation was 18 days. The arrangement and results of the experiment are indicated in Table 9.

TABLE 9.—*Comparison of $CaCO_3$ and $CaSiO_3$ in their effect on nitrogen fixation.*

Test no.	Treatment	Mg. N in 10 g. soil	Average	Average increase over check
1	Check	19.18		
2		19.18	19.18	
3	No amendment	19.60		
4		19.32		
5		19.74		
6		19.46	19.53	.35
7	.2% $CaCO_3$	20.16		
8		20.44		
9		20.30		
10		20.30	20.30	1.12
11	.4% $CaSiO_3$	19.46		
12		19.60		
13		19.46		
14		19.32	19.46	.28
15	.8% $CaSiO_3$	20.44		
16		20.58		
17		20.16		
18		20.30	20.37	1.19
19	2% $CaSiO_3$	20.86		
20		21.14		
21		21.00		
22		20.72	20.93	1.75

Two tons of limestone promoted nitrogen fixation as much as did eight tons or more per acre of $CaSiO_3$. A part of the effect of the heavy applications of $CaSiO_3$ may have been due to increased aeration. Cowles, (8), in 1917 and Hartwell and Pember, (14), in 1920 found dicalcium silicate equal to limestone as a soil amendment. These results indicate that finely ground calcium silicate has some promise as a soil amendment.

Effect of Mineral Fertilizer Materials

Bear (2) found that the addition of phosphorus to some soils increased nitrogen fixation, and Wilfarth and Weinmer determined that large quantities of phosphorus are used by Azotobacter (33, 30).

Gerlach and Vogel (10) concluded that potassium is not essential to Azotobacter metabolism; but Vogel (31) later, in 1912, decided that potassium does favor their development.

Using Volusia silt loam, an experiment was started on April 26, 1922, to determine the need for phosphorus and potassium by the nitrogen-fixing organisms. The incubation period was 22 days. The

arrangement of the experiment and the data secured are shown in Table 10.

TABLE 10.—*Effect of soluble nutrients on nitrogen fixation.*

Test no.	Treatment	Mg. N in 10 g. soil	Average	Average increase over checks
1	Check, dried at 100° C	18.76		
2		18.76	18.76	
3	.2% $CaCO_3$	20.44		
4		20.58		
5		20.72		
6		20.86	20.65	1.69
7	.01% K_2SO_4	20.72		
8		20.58		
9		20.86		
10		21.00	20.79	1.83
11	.01% KH_2PO_4	20.86		
12		20.44		
13		20.72		
14		20.58	20.65	1.69

In these experiments, as shown in Table 10, neither phosphorus nor potassium gave any significant effect on the amount of nitrogen fixed. Although this soil responds to fertilizers for field crops, it seems to contain enough soluble phosphorus and potassium for the needs of the nitrogen-fixing bacteria (34).

Effect of Nitrogenous Fertilizers

As the use of inorganic nitrogenous fertilizers is on the increase, it was thought well to determine the effect of varying quantities of $NaNO_3$, $Ca(NO_3)_2$, and $(NH_4)_2SO_4$ in quantities ranging from 100 to 1000 pounds per acre on nitrogen fixation in the soil. Volusia silt loam was used and incubation was from October 10 to October 31, 1922. Five milligrams of $NaNO_3$ to 100 grams of soil equals 100

TABLE 11.—*Effect of varying quantities of $NaNO_3$, $Ca(NO_3)_2$, and $(NH_4)_2SO_4$ on nitrogen fixation.*

Treatment	Mg. N in 10 g. soil	Average increase over check	Gain or loss over no treatment
Check	14.84		
No treatment	15.26	.42	
5 mg. $NaNO_3$	16.80	1.96	1.56
10 " "	16.80	1.96	1.56
25 " "	15.68	.84	.42
50 " "	15.12	.28	—.14
5 mg. $Ca(NO_3)_2$	17.36	2.52	2.10
10 " "	17.36	2.52	2.10
25 " "	15.68	.84	.42
50 " "	15.12	.28	—.14
4 mg. $(NH_4)_2SO_4$	16.52	1.68	1.26
8 " "	16.24	1.40	.98
20 " "	14.98	.14	—.28
40 mg. $(NH_4)_2SO_4$	14.84	.00	—.42
.5gm. $CaMgCO_3$	18.48	3.64	3.22
.5gm. $CaCO_3$	17.64	2.80	2.80

pounds $NaNO_3$ per acre. The results of these tests are shown in Table 11.

The 100 and 200 pound applications of $NaNO_3$ and $Ca(NO)_2$ both stimulated nitrogen fixation, but 500 and 1000 pounds per acre depressed it. $Ca(NO_3)_2$ had a greater stimulating effect than did equal additions of $NaNO_3$.

Eighty pounds $(NH_4)_2SO_4$ per acre stimulated nitrogen fixation somewhat, but there was a rapid falling off with larger applications.

As a further check on the nitrate treatments, dolomite and pure calcium limestone were used alone for comparison. Both of these increased the amount of nitrogen fixed more than did any of the nitrates. The dolomite was better than $CaCO_3$ in this respect.

Several investigators (11) have found that small quantities of nitrates stimulate nitrogen fixation and large quantities discourage it. The work of Hills (13) indicates that nitrates encourage the multiplication of Azotobacter, but decrease their individual efficiency.

From the standpoint of the use of commercial fertilizers in crop production, it is encouraging to know that applications of nitrates similar to those used in practice do not decrease the effects of the nitrogen-fixing bacteria.

Effect of Soluble Aluminum and Iron

Tables 12 and 13 show the results of experiments with soluble aluminum and iron through 21 days of incubation. One one-hundredth

TABLE 12.—*Influence of soluble aluminum on nitrogen fixation and the counteracting effect of limestone.*

Test no.	Treatment	Mg. N in 10 g. soil	Average	Average increase over check
1	Checks, dried at 100° C	18.76		
2		18.76	18.76	
3	None	20.40		1.64
4	.01% Al_2Cl_6	19.46		
5		19.60		
6		19.46		
7		19.32	19.46	.70
8	.02% Al_2Cl_6	19.18		
9		19.32		
10		19.04		
11		19.18	19.18	.42
12	.03% Al_2Cl_6	18.48		
13		18.34		
14		18.62		
15		18.20	18.41	—.35
16	.03% Al_2Cl_6 and .4% $CaCO_3$	20.58		
17		20.30		
18		20.16		
19		20.58	20.23	.147
20	.2% $CaCO_3$	20.44		
21		20.16		
22		20.58		
23		20.44	20.40	1.64

TABLE 13.—*Effect of soluble iron on nitrogen fixation.*

Treatment	Average mg. N in 10 g. soil	Increase over check
Check	18.76	
None	20.40	1.69
.01% $FeCl_3$	20.93	2.17
.02% "	21.59	2.83
.03% "	21.35	2.59

percent $AlCl_3$ permitted a small amount of nitrogen fixation, but all quantities used had a depressing effect. Large amounts were very toxic. These results do not agree with those of Kaserer (17) who states that aluminum stimulates nitrogen fixation. In these experiments, the $AlCl_3$ probably increased the soil acidity. In all cases, the application of limestone counteracted the toxicity of the aluminum.

Soluble ferric chloride in all quantities used, from .01% to .03%, stimulated nitrogen fixation. As suggested by Söhngen (29), this may be due to a colloidal effect of the iron in adsorbing the oxygen and nitrogen of the air and bringing them into more intimate contact with organisms. A quantity of Volusia silt loam was tested, six days after treatment with iron chloride, for the presence of soluble iron by the KSCN test, in comparison with another quantity not so treated. The results indicated a larger quantity of soluble iron in the treated soil. This indicated the validity of Söhngen's suggestion.

Prazmowski (27) found inorganic colloids effective on bacterial activities only in the presence of organic colloids.

SUMMARY

In the Volusia soil, with a high lime requirement, and in the Dunkirk soil, with a low lime requirement, one ton of limestone per acre promoted nitrogen fixation about as much as any heavier application did.

There was practically no difference between the effect of equivalent amounts of calcium as limestone and as burned lime on the nitrogen fixing bacteria.

Dolomitic limestone proved to be better than pure calcium limestone.

Rapid nitrogen fixation in the soil is at first accompanied by a decrease in nitrates, probably due to the assimilation of the nitrates by the organisms.

Gypsum gave no significant results in its effect on nitrogen fixation.

Two tons $CaCO_3$ promoted nitrogen fixation as much as eight tons $CaSiO_3$.

Soils may respond to the use of mineral nutrients for field crops and yet contain enough soluble minerals, as phosphorus or potassium to supply the requirements of the nitrogen fixing organisms.

Under the conditions of the experiment, one hundred pound applications of $NaNO_3$, or its equivalent in $(NH_4)_2SO_4$ or $Ca(NO_3)_2$, stimulated nitrogen fixation; but heavy applications depressed it. These results indicate that the judicious use of nitrogenous fertilizers does not interfere with nitrogen fixation.

When soil conditions are made favorable for nitrogen fixation, inoculation is unnecessary, for the two soils used.

Small quantities of $AlCl_3$ depressed nitrogen fixation; but iron chloride stimulated it, possibly because of its colloidal effect.

The quality of the organic matter added is as important as the quantity. Horse manure was the most valuable of any of the materials added in these experiments.

Composting organic materials, before adding them to the soil, hastens nitrogen fixation during the first six weeks after application.

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LITERATURE CITED

1. Ashby, S. F. Some observations on the assimilation of atmospheric nitrogen by a free living soil organism. *In* Amer. Jour. Sci., 8:337. 1907.
2. Bear, Firman E. A correlation between bacterial activity and lime requirements of soils. *In* Soil Sci., 4:433–462. 1917.
3. Beijerinck, M. W. Ueber Oligonitrophile Mikroben. *In* Cent. Bakt., Ab't. 2, 7:561–582. 1901.
4. Berthelot, M. Recherches nouvelles sur les micro-organisms fixateurs de l'azote. *In* Comp. Rend. Acad. Sci., (Paris), 15:569–574, 842–849. 1892.
5. Bouilhac, R. Sur la fixation de l'azote atmospherique par l'association des algues et des bacteries. *In* Comp. Rend. Acad. Sci., 23:828–830. 1896.
6. Christensen, H. R. Ueber das Vorkommen und die Verbreitung des Azotobacter chroococcum in verschiedenen Boden. *In*. Cent. Bakt., Abt. 2, 17:109–119, 161–165. 1907.
7. Christensen, H. R. Studien über den Einfluss der Bodenbeschaffenheit auf das Bakterienleben und dem Stoffumasatz im Erdboden. *In* Cent. Bakt., Abt. 2, 43:1–166. 1915.
8. Cowles, A. H. Calcium silicates as fertilizers. *In* Metal. and Chem. Eng. 17:664–665. 1917.
9. Emerson, Paul. Are all the soil bacteria and streptothrices that develop on dextrose agar azofiers? *In* Soil Sci., 3:411–421. 1917.
10. Gerlach, M., and Vogel, I. Weitere Versuche mit Stickstoffbindenden Bakterien. *In* Cent. Bakt., Abt. 2, 10:363–643. 1903.
11. Greaves, J. E. Azofication. *In* Soil Sci. 6:163–217. 1920.
12. Hall, A. D. The Book of the Rothamsted Experiments. pp. 138–141. London, Eng. 1917.

13. HILLS, T. L. Influence of nitrates on nitrogen assimilating bacteria. *In* Jour. Agr. Res. 12:183–230.

14. HARTWELL, B. L., and PEMBER, F. R. The effect of dicalcium silicate on an acid soil. *In* Soil Sci., 10:57–60. 1920.

15. HUTCHINSON, C. M. Soil bacteriology. *In* Rept. Agr. Res. Inst. and Col. Pusa (India). pp. 85–90, 1911–12.

16. JAMIESON, I. E. Power of green plants to fix atmospheric nitrogen. *In* Rept. Agr. Res. Assn., Aberdeen, England. 1905.

17. KASERER, HERMANN. The function of humus in cultivated soils. Abs. in Exp. Sta. Rec., 26:422, 1912.

18. KOCH, ALFRED. Ernahrung der Pflanzen durch frei im Boden lebende Stickstoffsammelnde Bakterien. *In* Ber. Deut. Landw. Gesell., 22:117–121.

19. KOSSOWITSCH, P. Untersuchungen ueber die Frage, ob die Algen freien Stickstofffixiren. *In* Bot. Ztg., 52:97. 1894.

20. LIPMAN, J. G. Experiments on the transformation and fixation of nitrogen by bacteria. N. J. Agr. Exp. Sta., 24th Ann. Rept. pp. 217–285. 1903.

21. ————. Soil bacteriological studies. N. J. Agr. Exp. Sta., 25th Ann. Rept. pp. 237–289. 1904.

22. LIPMAN, C. B. Nitrogen fixation by yeasts and other fungi. *In* Jour. Biol. Chem., 10:169–182. 1911.

23. ———— and TAYLOR, J. K. Proof of the power of the wheat plant to fixatmospheric nitrogen. Science, 56:605–606. 1922.

24. ———— and BURGESS, P. S. Studies on nitrogen fixation and Azotobacter forms in soils of foreign countries. Cent. Bakt., Abt. 2, 44:481–511. 1915.

25. LOHNIS, F., and GREEN, H. H. Über die Entstehung und die Zersetsung von Humus, sowie ueber dessen Einwirkung auf die Stickstoff Assimilation. Cent. Bakt., Abt. 2, 40:52–60. 1914.

26. MOCKERIDGE, F. A. Some conditions influencing the growth of Azotobacter and the fixation of nitrogen by the organism. *In* Ann. Bot., 26:871–887. 1912.

27. PRAZMOWSKI, A. Studies of nitrifying bacteria. Abs. in Chem. Abs., 8:1294, 1912.

28. RICHARDS, E. H. The fixation of nitrogen in feces. *In* Jour. Agr. Sci., 8:299–311. 1917.

29. SÖHNGEN, N. L. Einfluss von Kolloiden auf mikrobiologische Prozesse. *In* Cent. Bakt., Abt. 2, 38:621–647. 1913.

30. TRUESDELL, H. W. Effect of phosphorous on bacteria. *In* Soil Sci., 3:77–98. 1917.

31. VOGEL, J. Untersuchungen über das Kalibedurfnis von Azotobacter. *In* Cent. Bakt., Abt. 2, 32: 411–442. 1912.

32. WEIS, F. and BORNEBUSCH, C. H. The presence of Azotobacter in Danish woods and the value of Azotobacter cultures for the determination of lime requirement in woodlands. Abs. in Internat. Inst. of Agr., Bul. Agr. Intell. Pl. Dis. 546–548. 1914.

33. WILFARTH, H., and WEINMER, G. Influence of mineral fertilizers on nitrogen assimilation by lower organisms. Abs. in Chem. Abs., 1:2810. 1907.

34. WINOGRADSKI, S. Sur l'assimilation de l'azote gaseux de l'atmosphere par les microbes. *In* Compt. Rend. Acad. Sci., 118:353–355. 1894.

35. YAMAGATA, UNOKICHI, and WILSON, J. K. Unpublished data, Cornell University. 1922.

SOME MISAPPLICATIONS AND LIMITATIONS IN USING STUDENT'S METHOD TO INTERPRET FIELD EXPERIMENTS[1]

S. C. SALMON[2]

In a recent publication,[3] which presents the results secured with certain fertilizer treatments on wheat, corn, oats, clover and timothy grown in rotation, it is concluded that "Student's method of calculating odds is a sound, simple criterion in furthering an explanation of the results obtained." This assertion, considered with the discussion which precedes it, may be taken to imply that a statement of the odds as calculated by Student's method in favor of any treatment is a sound or safe measure of accuracy. Student's method is a valuable aid in evaluating experimental results; but it is doubtful if so sweeping a recommendation is justified at the present time. Furthermore, so much has been written in favor of this method and so many experiments are being interpreted in accordance with it, that it seems desirable to call attention to some limitations which must be considered if errors and misapplications are to be avoided.

Two main criticisms may be offered. The first relates to those fertilizer and tillage experiments (and possibly others) in which a given plot or tract of land receives the same treatment year after year. The second is more general and is related to the fact that Student's method measures the uniformity or consistency of a gain for a given treatment or variety regardless of whether the variable gains are due to experimental errors or to a differential response to environmental factors.

It is generally recognized that fertilizer and tillage experiments are subject to several possible sources of error. Among these may be mentioned errors in measuring plots, errors in harvesting, thrashing and weighing the grain, differential damage by birds and rodents, variation in the moisture content of the harvested product, and soil heterogeneity. It is probably a fair statement that with careful work and constant attention, soil heterogeneity is more important than any of the others. Yet, it is with respect to this source of error that Student's method may entirely fail. Consider, for example, two plots

[1]Contribution No. 155, Department of Agronomy, Kansas Agricultural Experiment Station. Received for publication August 20, 1924.

[2]Professor of Farm Crops.

[3]GEO. L. SCHUSTER. Fifteen years of field experiments with manure, fertilizers and lime on sassafras silt loam soil. Del. Agr. Exp. Sta. Bul. 137 (Tech. Bul. 4) 1924.

in an experiment to determine the effectiveness of lime, one of the plots being limed and the other unlimed. The odds may be calculated to show that the yield of one is significantly higher than the other. But does this necessarily show that the higher yield is due to the application of lime? Obviously not, since the limed plot might have had a higher lime content at the beginning of the experiment, so that the same result would have been secured without the application.

To make the point clear, consider the yields of plots 5 and 8 in an experiment relating to the preparation of the ground for wheat on the agronomy farm at Manhattan, Kansas. There are eleven plots in the original experiment of which these two are a part. The yields are shown in Table 1.

TABLE 1.—*Annual yields of plots 5 and 8 in a seedbed preparation experiment Manhattan, Kansas.*

	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	Average
Plot 5	14.5	7.8	16.3	21.7	10.3	5.6	11.8	7.2	11.4	6.8	11.4
Plot 8	18.8	10.6	18.8	27.9	17.5	5.8	14.5	7.7	15.7	9.3	14.7

Average gain for plot 8 = 3.3 bushels
σ = 2.12
Z = 1.558
Odds = 1719 to 1

Without further information than has been given one would conclude that the treatment of plat 8 has produced highly significant increases in yield. The true situation, however, is that this plat was a more productive one than is plat 5, as shown by the fact that both are check plats and have received identical treatment throughout. The high odds merely show that plat 8 has yielded consistently higher than plat 5 and that the errors associated with harvesting, thrashing and weighing the grain, and others of a similar nature have been very small, or at any rate, not enough to over-balance the difference in soil. Obviously, of course no investigator would claim that other differences in this same experiment are significant merely because the odds in their favor are very high?

The writer has no disposition to question the conclusions reached with respect to the effectiveness of different fertilizer treatments discussed in the publication referred to above. Is it not possible, however, with the information given and considering the above facts, to assume that some of the differences considered as highly significant are in reality due to soil heterogeneity or some such systematic error? Consider, for example, the high gain secured for lime on corn when applied with potassium as recorded for plat 4 (in Table X, page 19) and no gain when applied with any other fertilizer treatment including four treatments which include potassium. Is it not possible that plat 4 was more deficient in lime at the beginning of the experi-

ment than the others? There may be plenty of evidence to disprove this assumption but can the fact that the odds are high be considered as proof?

The real difficulty in experiments of this sort is the fact that the odds as calculated depend primarily upon the consistency with which a given treatment yields higher than another from year to year rather than from plot to plot. It is obvious that in the first example Student's method affords no means of determining whether significant differences are due to treatment or to soil heterogeneity and in the second a very imperfect means since only four different plots are involved in the 15 years of the experiment.

Perhaps it should be pointed out that errors may occur in interpreting any experiment, regardless of what method of interpretation is used. The point here is that Student's method fails to take into account one of the most important sources of error and because it measures the consistency of results secured over a period of years is very likely to give a false sense of security.

The second feature of Student's method which it is desired to discuss may be illustrated fairly well by the results presented in Table 2 (page 11) of the above-mentioned publication. This table shows the increases in yield of oats due to various fertilizer treatments. Plat 7, which was treated with phosphorus and potassium, has produced an average gain of 6.1 bushels per acre, with odds of 908 to 1; whereas plat 14, treated with manure, produced an average gain of 9.3 bushels per acre but with the very small odds of 7 to 1.

In other words the relatively high average gain of 9.3 bushels per acre is considered of no consequence because of the small odds whereas a gain of 6.3 bushels is considered highly significant. The author justifies this conclusion by pointing to the fact, that, whereas the gain for plat 7 was very consistent from year to year, that of plat 14 was not. But is he positively justified in this conculsion? Is the fact that the crop responded to phosphorus and potassium every year while it responded to manure only four years out of the six with no loss in the other two years (as shown in Table A, page 30) proof that manure is inferior to phosphorus and potassium? Are there not good reasons to believe that the response of a crop to manure is dependent upon seasonal conditions, perhaps quite different from those which will permit it to respond to commercial fertilizers? If this is admitted must we conclude, as the author has done in this particular case, that the "average gains are not to be relied upon?"

Speaking in more general terms, a casual examination of Student's method will show that the odds depend upon the ratio between the

mean difference and the standard deviation of the differences. It is clear then that, with a given mean difference, the odds will increase as the standard deviation decreases and *vice versa*. The standard deviation obviously depends upon the consistency or uniformity of the differences. For example, if it were possible to have a constant difference between two varieties or treatments for a term of years the standard deviation would become zero and the odds infinite. If, on the other hand, the differences fluctuate, being very large one year, moderate another year and very small a third year, the standard deviation of those differences will be large and the odds very small.

For example, take the hypothetical case mentioned by Love and Brunson[4] in which two varieties, A and B, are compared in two cases. There is a gain for variety A in each case of 0.5 bushel and the odds are of course infinite. The example was used by Love and Brunson to illustrate the uncertainty in applying Student's method to as few as two pairs of observations, but the same result will be secured if applied to any greater number providing only that the difference in yield between the two in every case is the same. Suppose one adds to this hypothetical case by assuming yields for three other instances making a total of five. To make the results more easily understood assume also that each result is for a different year as follows:

Year	Variety A	Variety B	Gain	D	D^2
1912	24.5	24.0	0.5	0	0
1913	27.0	26.5	0.5	0	0
1914	30.0	29.5	0.5	0	0
1915	15.0	14.5	0.5	0	0
1916	35.0	34.5	0.5	0	0

$$\text{Mean} = 0.5 \quad \sigma = 0$$

$$Z = \frac{0.5}{\sigma} \quad P = 1.000$$

Odds are infinite

Now consider the result if, say in 1912, variety B, because of susceptibility to rust damage, winterkilling or any one of an almost infinite number of varietal factors, produced but 8 bushels per acre, whereas A, not being damaged, produced the yield indicated in the table. Suppose a similar result occurred in 1914 and in 1916 and B produced only 10 bushels and 5 bushels per acre, respectively, the yields of A in each case remaining the same. Agronomically speaking, these facts would greatly increase one's belief in the superior value of

[4]H. H. Love and A. M. Brunson. Student's method of interpreting paired experiments. *In* Jour. Am. Soc. Agron. 16:60–68. 1924.

variety A, but the odds as calculated by Student's method are reduced to 24 to 1, and the difference in yield must therefore be considered as not significant.

It is admitted that the above case is exaggerated somewhat to make the point clear, but is it unreasonable to expect closely analogous cases in practice? What about a comparison of rust-resistant and non-resistant spring wheats, in the spring wheat belt where rust is intermittent; cold-resistant and non-resistant winter wheats, in the winter wheat belt; stiff-strawed and weak-strawed varieties, in areas where lodging is likely to occur; early plowing for wheat as compared with late plowing, where the expected beneficial results of early plowing depend upon rainfall; the effect of manure, in sub-humid areas and possibly in others where the effect depends greatly on climatic conditions? Are there not numerous experimental results concerning which a strict application of Student's method would lead to serious errors?

One need not conclude from the above that Student's method is of no value. There are, no doubt, many cases where differential response will not be secured and where this method can be used to advantage. But the facts stated above illustrate the very great danger of blind adherence to a formula and the need for examining a proposition from all angles before deciding definitely in its favor.

Investigators must learn that plausibility is not proof, that there is no royal road to accuracy in experimental work, and that in analysing experimental data nothing so far discovered can take the place of clear thinking, good judgment and common sense.

THE PROBLEM OF SOIL ORGANIC MATTER AND NITROGEN IN DRY-LAND AGRICULTURE[1]

J. S. Jones and W. W. Yates[2]

In the northern inter-mountain and Pacific northwest states vast areas of easily tilled lands have been developed by dry-farming methods. While other farmers may employ to a limited extent the practices of the dry farmer, strictly speaking, dry farming implies a yearly rainfall that is insufficient for the annual production of farm crops.

[1]Contribution from the Oregon Agricultural Experiment Station, Corvallis, Ore. Published with the approval of the experiment station committee on soils and the superintendent of the Sherman County Branch Experiment Station. Received for publication September 17, 1924.

[2]Professor in charge of the Division of Agricultural Chemistry, and Assistant Chemist, respectively.

That condition makes necessary the summer-fallow system. In the most favored regions, the summer-fallowed land receives and largely retains the maximum rainfall (15 to 18 inches) which characterizes a strictly dry-farming area. It is followed by two years of cropping. In less favored regions, the yearly precipitation of 10 to 14 inches strictly limits crop production to alternate years. Few farmers have the hardihood to attempt dry-farming operations in regions of less than 10 inches of annual rainfall.

Dry farming has been successfully practiced in certain sections of the inter-mountain country for several decades and the various sections of the far west that can be developed by dry farming methods are now pretty thoroughly differentiated. Dry-land experiment stations, advantageously located and maintained cooperatively by the Bureau of Plant Industry of the United States Department of Agriculture and various state agricultural colleges, are aggressively investigating the many and varied agronomic problems encountered by the dry farmers. The general principles involved in the storage and conservation of rainfall have come to be pretty thoroughly understood and practiced. This is true also of the limitations imposed by the annual precipitation for the various sections and the summer-fallow system upon the kind and frequency of cropping. Dry-farmed sections of the inter-mountain and Pacific northwest states are essentially small grain sections and of necessity must continue as such. Wheat is the standard crop. When properly chosen as to variety, the wheat of dry-farmed areas is unexcelled for milling purposes.

The location of dry-land experiment stations in various sections of the far west would imply that various agronomic problems, in part at least, are local in character. This is true. The testing of varieties for local adaptation; the improvement of varieties by selection and hybridization; the determination of the best tillage methods for the summer fallow, of proper depths of seeding and of the best rate and time for seeding; are all lines of work that are commonly thought of as having chiefly a local significance. There are some problems which are now developing in dry-land farming, however, whose solution will have a general application. Prominent among these, if not the most prominent, are those problems which involve considerations of soil fertility and the lasting or permanent productivity of dry-farmed lands. In view of the limitations imposed by rainfall and the summer-fallow system upon a free choice of crops, experiment station groups, and farmers, too, cannot help wondering what the future of dry-farmed areas may be in the matter of productivity.

Potentially these dry-farmed soils, as a rule, are exceedingly rich in the mineral elements required for crop growth. Their weak point, in comparison with grain lands of humid sections, is a decidedly lower content of organic matter and of the element nitrogen which is always closely associated with it.

Perhaps no facts in soil technology are more firmly established than that tillage of any soil speeds up oxidation, or the "burning out" of its organic matter, and the liberation from insoluble substances of those chemical elements that are necessary for crop growth. Indeed, the chemical activity resulting is roughly in keeping with thoroughness of tillage. In humid climates, and where irrigation is practiced, the rapid destruction of organic matter by intensive cultivation may be sought deliberately with safety and advantage. *Actively* decaying organic matter makes for good tilth and fertility. Losses can be made good almost at will by the judicious use of cover and green manuring crops and, if legumes are freely grown for that purpose, an adequate supply of nitrogen can also be maintained.

But, however necessary tillage may be to conserve moisture and prepare readily available chemical elements for the benefit of succeeding crops, this destruction of the soil's original content of organic matter (always low in the dry-farmed lands of the regions in question) cannot be viewed with the same degree of unconcern by the dry farmer as it may be by one who farms in a humid climate or by the practice of irrigation. It is a matter of common observation and comment that the very choicest of lands, when given over for several generations to the exclusive growing of small grains, invariably develop marked differences from the original condition in the matter of tilth and fertility. The occasional appearance of "run together" condition and the tendency to wash, or gully, with the least movement of surface water are danger signals which farmers themselves recognize, but to which, under normal dry-farming conditions, they can give but little heed. No cover or green manure crop appears at this time to be even remotely practicable for the vast areas of dry-farmed lands that receive the smaller amounts of rainfall.

THE LOWER COLUMBIA RIVER BASIN

In Oregon, one extensive area of dry-farmed lands, comprising the five large counties (Morrow, Gilliam, Sherman, Umatilla and Wasco) which border on the Columbia River just east of the Cascade range of mountains, is known as the grain section of the lower Columbia River basin. The section is a rolling plateau whose annual precipitation averages, over by far the larger part, approximately 12 inches.

Parts of this area have been in cultivation for fifty years or more. Other parts have been much more recently broken up. Within this area a farm of 230 acres at Moro, Sherman County, has been operated as a dry-land experiment station for fourteen years. Scant as is the rainfall for this area, the experiments at this station have repeatedly shown that good summer-fallow tillage insures yields of wheat ranging up to as high as 35 bushels per acre. A consideration of well-founded agronomic principles is sufficient, of course, to convince one that this process is an exhaustive one for soil organic matter and for nitrogen, too, since, roughly speaking, the production of each bushel of wheat involves the delivery by the soil to the crop of two, or more, pounds of nitrogen. With 3000 pounds of nitrogen as the total for three-fourths of an acre-foot and no adequate means in sight for replenishing the original stock when depleted, there appears to be abundant reason why all dry-land experiment station groups should feel deeply concerned over soil productivity problems.

ANALYTICAL DATA ON LOSSES OF ORGANIC MATTER AND NITROGEN

In taking stock of the situation for lower Columbia River basin soils, it appears advisable to check up at stated intervals on actual losses of soil organic matter and nitrogen. Quantitative evidence in support of conclusions one might arrive at from theoretical considerations only is frequently useful, particularly in discouraging certain objectionable practices on the part of some dry farmers who have not yet, apparently, thought much beyond the present. For example, all too frequently still, in some dry-land sections of the northwest, stubble and straw are deliberately burned.

The first work of this kind for this particular area was done by Bradley (2)[3], previous to the establishment of the experiment station at Moro. The data secured recently are more extensive. Highways radiating from Moro and occasional fields still afford opportunity for securing samples of soil that has never been turned by the plow or other cultivating tool. The native vegetation (short sage brush and fine wild grasses) is frequently very plainly in evidence; while in adjoining fields, just a few feet distant, there is an area of the same soil type that has been given over for from twenty to thirty years to the growing of wheat or other small grain.

Soil samples which fairly represented the cropped and virgin soils of the section immediately surrounding Moro were secured recently for laboratory examination. The samples were each composited

[3]Reference by number is to "Literature Cited", p. 731.

from several "drives" of the King soil sampler at points distant from each other by from three to five rods. The analytical work was performed at the central experiment station. Before analysis, the samples were thoroughly mixed and screened through a fifty-mesh screen. Moisture was determined by drying to constant weight at 103° C; organic matter by the loss-on-ignition method; and inorganic carbon, organic carbon and nitrogen by the official methods of the A. O. A. C. Organic carbon determinations were made to check the determination of organic matter by the loss-on-ignition method. Inorganic carbon determinations were necessary to secure organic carbon; and, incidentally, they gave the necessary data for calculating the soil's content of limestone (not reported here but ranging, in the surface soil, from .5 percent to 1.3 percent).

The soils were sampled in foot sections to a depth of four feet. Samples representative of the first and second feet only have thus far been analyzed but it is believed that the data secured from them clearly indicate what is taking place in the cropped soils. Calculations are based on the dry soil.

TABLE 1.—*Organic matter and nitrogen in cropped and virgin soils of Sherman County.*

Location	Soil	Organic matter percent	Organic carbon percent	Nitrogen percent
First foot				
1	Cropped	2.28	1.068	.099
	Virgin	2.77	1.314	.110
2	Cropped	2.76	1.220	.109
	Virgin	2.87	1.283	.116
3	Cropped	2.30	1.013	.079
	Virgin	2.54	1.052	.096
4	Cropped	2.06	1.068	.082
	Virgin	2.81	1.240	.101
5	Cropped	2.33	1.166	.096
	Virgin	2.86	1.216	.106
6	Cropped	2.80	1.196	.106
	Virgin	2.88	1.283	.123
Average	Cropped	2.42	1.120	.095
	Virgin	2.79	1.238	.109
Second Foot				
1	Cropped	2.02	.830	.075
	Virgin	2.41	.912	.096
2	Cropped	1.64	.830	.076
	Virgin	2.10	.946	.086
3	Cropped	1.72	.746	.070
	Virgin	2.28	.924	.084
4	Cropped	1.92	.737	.067
	Virgin	1.87	.807	.082
5	Cropped	1.89	.717	.074
	Virgin	2.59	1.022	.096
6	Cropped	1.86	.779	.075
	Virgin	1.84	.847	.081
Average	Cropped	1.84	.772	.073
	Virgin	2.17	.909	.087

In every instance, whether organic matter to be taken as derived by the direct method, or calculated by the use of an arbitrary factor (as 2¼) and the organic carbon determination, the first foot of cropped soil is lower in its content of this constituent which makes for good tilth and greater water-holding capacity than is the adjacent virgin soil. For the most part the same statement holds true for the second foot. Small as these differences in organic matter appear, when expressed on the percentage basis, they signify differences in dry organic matter of something like six and one-half or seven tons in each of the first two acre-feet. It must be said that there is no striking evidence that this decline in organic matter, under the present system of cropping, has operated to lower yields in the vicinity of Moro, or to bring about markedly poor conditions of tilth. It is certain, however, that results of that kind will in time develop. It is the story of all similar grain lands. Certainly any investigation that seeks for a means of arresting this decline is abundantly justified.

There is evident, too, a small but positive decline in the nitrogen content of these soils under constant cropping to small grain. Again, small as the differences appear when expressed on the percentage basis, they actually amount on the average to approximately thirteen and seventeen percent of the original nitrogen content of the first and second foot respectively. The first two feet of cropped soil are lower in nitrogen than the first two feet of virgin soil by some eight or nine hundred pounds per acre. Since this is a larger amount than can be accounted for by the nitrogen used by fifteen, or even twenty, crops of grain, there must be some loss of nitrogen from these soils under cultivation through processes not yet thoroughly determined.

It is known from experimental data that the accumulation of nitrogen in nitrate form in the surface foot of an acre of thoroughly tilled summer fallow by early fall is large[4] and that nitrogen in nitrate form invariably disappears from these soils with the advent of winter temperatures. Circumstances strongly indicate some loss of nitrogen annually through processes of denitrification.

There is, of course, nothing original in this offering of proof that the soils of this particular area are undergoing, under cultivation, appreciable losses of organic matter and nitrogen. Thatcher (7) has made similar observations for eastern Washington soils and Stewart (5) for the dry-farmed section of Utah. More recently, Sievers and Holtz (3) have published analytical data in support of the same conclusion regarding an extensive area of dry-farmed lands in Washing-

[4]Expressed as $NaNO_3$, it may reach a total of 150–175 pounds.

ton known as the Central Columbia River Basin. Moreover, Alway and Turnbull (1) in Nebraska, and Swanson and Latshaw (6) in Kansas, have noted even larger losses of the same nature from dry farmed prairie soils. From our own and other recorded analytical data a safe conclusion is that wherever the summer-fallow system prevails in the growing of small grains the steady decrease of soil organic matter and nitrogen in significant amounts is a fact.

CROP ROTATIONS IN SOIL FERTILITY PROBLEMS

Dry farmers of the Inter-mountain and Pacific northwest states adhere very closely to the wheat—summer fallow rotation. In the light of their experience wheat, doubtless, is the most profitable of the small grains. The experiment station at Moro, however, has made it possible to secure some actual data bearing upon that point. For a number of years, twelve acres on the experiment station farm have been given over to a series of rotations that are intended primarily to yield data from which one can judge whether the wheat-summer fallow system is in reality the most feasible and profitable for these lands. That section of the farm presents a most favorable opportunity, too, for a study of the influence of various rotations on soil organic matter and nitrogen. It seems that some of these might be expected to slow up the depletion of soil organic matter and possibly save for the soil a little nitrogen over the straight wheat-summer fallow practice. The first work on these rotation plats with these points in view has been completed with results that are summarized for study in Table 2. The two or more plats that make up any one rotation are each represented in the Table by a composite sample secured by the thorough mixing of four single "drives" of the soil tube as the plat was traversed diagonally. The plats are eight rods in length by two in width. It can be shown from analytical data that they are remarkably uniform in the soil components under discussion. The determinations were made by methods previously outlined.

Table 2 is so arranged that one may make comparisons between any rotation and the average for *all* check plats (winter wheat-fallow) or the average for the two or three *nearest* check plats. It is to be noted that when these plats were sampled no rotation had extended beyond eleven years. The last three were in their ninth year. It is believed that too little time has passed to permit of any very positive conclusions as to the relative advantage of the various rotations in relation to this particular soil fertility problem. A few brief comments only are pertinent.

TABLE 2.—*Organic matter and nitrogen in the soil of rotation plats on the Sherman County Branch Experiment Station.*

Rotations	Number of plats sampled and averaged	First Foot Organic matter	First Foot Organic carbon	First Foot Nitrogen	Second Foot Organic matter	Second Foot Organic carbon	Second Foot Nitrogen
		Percent	Percent	Percent	Percent	Percent	Percent
1. Check plats winter wheat-fallow	12	2.24	.972	.088	1.62	.744	.068
2. Spring wheat-spring wheat-fallow	3	2.39		.090	1.65		.074
Check plats (873–8)	2	2.02	.976	.086	1.78	.769	.068
3. Spring barley-spring barley-fallow	3	2.15		.087	1.78		.072
Check plats (773–8)	2	2.20	.953	.093	1.90	.709	.071
4. Spring wheat-spring barley-fallow	3	2.19		.086	1.58		.068
Check plats (973–8)	2	2.11	.984	.082	1.40	.730	.067
8. Spring wheat-spring barley-corn	3	2.49		.088	1.74		.071
Check plats (873–8)	2	2.02	.976	.086	1.78	.769	.068
9. Spring wheat-corn-spring barley	3	2.76		.094	2.05		.075
Check plats (773–8)	2	2.20	.953	.093	1.80	.709	.071
10. Spring wheat-spring barley-potatoes	3	2.28		.090	1.70		.067
Check plats (973–8)	2	2.11	.984	.082	1.40		.067
5. Spring wheat-corn-spring wheat-fallow	4	2.05		.086	1.57		.068
Check plats (883–8)	2	2.19		.089	1.63		.065
6. Spring wheat-fallow spring wheat-peas	4	2.41		.084	1.40		.064
Check plats (983–8)	2	2.40		.088	1.35		.065
17. Spring wheat-spring barley-fallow-corn	4	2.03		.089	1.53		.063
19. Peas continuously	3	2.19		.088	1.38		.064
7. Spring wheat-spring barley-pea fallow-fallow	4	2.39		.089	1.55		.069
Check plats (983–8)	2	2.40		.088	1.35		.065
11. Spring wheat-spring barley-rye fallow-corn	4	2.34		.091	1.76		.074
Check plats (883–8)	2	2.19		.089	1.65		.065
12. Spring wheat-spring barley-pea fallow-corn	4	2.56		.101	2.18		.076
Check plats (873–8)	2	2.48		.091	1.70		.074
13. Spring wheat-spring wheat-pea fallow-spring barley	4	2.30		.095	1.58		.077
Check plats (783–8)	2	2.48		.091	1.70		.074
14. Winter wheat-corn-winter wheat-pea fallow-winter wheat-potatoes	6	2.26		.086	1.67		.066
Check plats (773–873–973)	3	2.12		.092	1.66		.069
18. Spring wheat-spring barley-manured fallow-corn	4	2.34		.088	1.57		.063
Check plats (all)	12	2.24	.972	.088	1.62	.744	.068
Average for all rotations	59	2.32		.089	1.66		.069

Roughly, and for the immediate purposes of this discussion, it will be noted that these rotations fall into one or another of four groups:

Rotations 2, 3 and 4 involve the growth of two small grain crops previous to the season of fallow. This procedure is practiced in dry-land regions of greatest rainfall, but is impracticable for the Lower Columbia River Basin. The less frequent appearance of the bare summer fallow might reasonably be expected to slow up the rate of oxidation of the soil's organic matter. On the other hand, the greater number of grain crops removed within a given period of time should prove to be more exhaustive of its nitrogen content. In so far as these figures may be accepted as proof, the expectation in regard to organic matter is realized in two of the three rotations. For nitrogen, it is realized in one only.

In rotations 8, 9 and 10, there are grown two small grain crops and the bare summer fallow is replaced by a cropped summer fallow. In these rotations, the average soil content of organic matter and nitrogen exceeds that for the nearest check plats. In the two rotations in which corn appears the differences in organic matter are so marked in the surface foot that there is suggested at once the fertilizing value from this standpoint of corn roots. Again, however, for dry-farming lands, these rotations could be practicable for sections of greatest rainfall only.

Rotations 5, 6 and 17 have been extended one year over the ones previously noted. They have both a cultivated cropped fallow and a bare fallow. Differences between these rotations and the nearest check plats in the soil's content of organic matter and nitrogen are too small to be of any significance.

In rotations, 7, 11, 12, 13, 14 and 18 the practice of green manuring and the spreading of barnyard manure is introduced. The periodic turning under of one crop, or the incorporation of barnyard manure, ought to increase quite appreciably the total for organic matter, and the data show this in the majority of cases for both the first and second foot. Where peas is the crop turned under there would be expected a higher content of the soil's nitrogen. The differences in nitrogen content shown by the analytical data meet that expectation in the majority of rotations. Just why *all* rotations in this group have not substantially enriched the soil, with organic matter especially, is not clear. It is to be noted, however, that crops turned under are never heavy and that the greatest increase of organic matter came in those rotations in which corn is one crop.

Not included in any of the groups of rotations is No. 19. In comparison with averages for all rotation plats and for the twelve check

(winter wheat-fallow) plats this rotation has been more exhaustive of soil organic matter and has barely maintained the average nitrogen content for the first foot. The second foot has lost in nitrogen. The pea crop in this rotation is a cultivated crop. If it could be grown there without cultivation, as it is in dry-land sections of greater rainfall, its effect upon the soil composition might be different. It is important to note in this connection, however, for the bearing it may have on subsequent work, that of all of the rotations conducted on this small-scale plan this one heads the list in profits returned per acre. Winter wheat-fallow stands fourth in this respect.(4).

In conclusion it may well be noted that while the work presented here is the result of a serious attempt to get at the solution of a serious problem that all dry farmers sooner or later must face, the analytical data are not offered with any feeling of finality. These rotation plats will be continued indefinitely and in the course of some six or eight years the analytical work will be repeated. By that time perhaps some definite influence of the various rotations on soil productivity can be established.

SUMMARY

Vast areas of our northern Inter-mountain and Pacific northwest states are dry farmed. These lands are given over almost completely to the growing of small grains. Wheat is the most prominent. Summer fallowing is a necessary practice in dry-land agriculture of the Columbia River Basin, but one that is generally conceded to be particularly exhaustive of the soil's content of organic matter and conducive to excessive losses of soil nitrogen. The low precipitation necessitates summer fallowing in alternate years. Quantitative proof is given that soils in the lower Columbia River Basin have undergone very appreciable losses of organic matter and nitrogen in the comparatively short period of their agricultural development.

A field of rotation plats on the dry-land experiment station at Moro, Oregon, is planned for continuance over a long term of years. The nature of the rotations is such as would seem almost to guarantee that differences in effects upon soil productivity will eventually appear. The oldest rotations had extended over a period of eleven years when the first sampling of the soil for analytical work was made. From this first decade of crop rotations, no positive conclusions are warranted regarding differences in soil organic matter and nitrogen that may be traced eventually to them. What appear to be tendencies in certain directions, however, are pointed out.

Corn and potatoes in rotation with the small grains leave the soil enriched with organic matter, corn probably because of its extensive

root system, and potatoes because of the residues of tops. Unfortunately, neither crop seems to be a practicable possibility in dry-land sections of lowest rainfall.

Fallow crops, rye and field peas, turned under have thus far not all increased the organic matter content of the soil over that in plats alternately cropped to winter wheat and summer fallowed. It is noticeable that in this series the most substantial enrichment occurs in those plats on which corn is also included in the rotations. Field peas turned under (the pea fallow) substantially enrich the soil with nitrogen.

Nitrogen has thus far been maintained on plats that have grown field peas continuously, with crops removed, but organic matter is lower than in plats alternately cropped with winter wheat and summer fallowed.

LITERATURE CITED

1. Alway, F. J., and R. S. Trumbull. A contribution to our knowledge of the nitrogen problem under dry farming. *In* Jour. Indus. Engin. Chem., 2:135–138. 1910.
2. Bradley, C. E. Nitrogen and carbon in the virgin and fallowed soils of eastern Oregon. *In* Jour. Indus. Engin. Chem. 2:138–139. 1910.
3. Sievers, F. J., and H. F. Holtz. The silt loam soils of eastern Washington and their management. Wash. Agr. Exp. Sta. Bul. 166. 1922.
4. Stephens, D. E. Dry-farm crop rotation experiments at Moro, Oregon. Ore. Agr. Exp. Sta. Bul. 209.
5. Stewart, Robert. The nitrogen and humus problem in dry farming. Utah Agr. Exp. Sta. Bul. 109. 1910.
6. Swanson, C. O., and W. L. Latshaw. *In* Soil Science, 8:1–39. 1919.
7. Thatcher, R. W. The nitrogen and humus problems in dry farming. Wash. Agr. Exp. Sta. Bul. 105. 1912.

WHEAT YIELD AND RAINFALL IN OHIO[1]

F. A. Welton and V. H. Morris[2]

INTRODUCTION

In a previous paper (5)[3], dealing with wheat yields following potatoes, it was suggested that the high yields thus obtained may be due, in part, to a high nitrate content of the soil and that the accumulation of nitrates may, in turn, be dependent on low rainfall. If this be true, then it follows that high yields of wheat following potatoes are related to low rainfall, for the reason that the latter permits a greater accumulation of nitrates than does high rainfall.

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[3]Reference by number is to "Literature Cited", p. 750.

If high yields of wheat following potatoes are dependent indirectly on moderately dry weather, then to the same condition, perhaps, may be ascribed the reason for the outstandingly high yields which are obtained in certain seasons. It is a matter of common knowledge that unusually high yields are produced occasionally. For example, 1917 was such a year. In that season the average yield for Ohio was 22 bushels per acre, or 5.2 bushels above the average for the decade 1911–1920.

The purpose of this paper is to consider the relationship between wheat yield and rainfall under Ohio conditions. Such an inquiry is of moment because the premise that high wheat yield is dependent on low rainfall is not universally accepted. Indeed, by some authorities, it is claimed that in Ohio there is no relationship between wheat yield and rainfall; that the latter is always sufficient and is never great enough to affect the yield adversely.

MATERIAL USED IN THIS STUDY

Two classes of data have been used in the preparation of this paper. These are wheat yield and rainfall records obtained at four of the experimental farms operated by the Ohio agricultural experiment station, the central farm located at Wooster, Wayne County, and the three district farms, one located at Germantown, Montgomery County, one at Carpenter, Meigs County, and one at Strongsville, Cuyahoga County. These farms are well distributed over the state and the records, therefore, are based on soil and climatic conditions fairly typical of the state as a whole. They cover periods ranging from 19 to 35 years. At each farm, the wheat yields used are those produced by a fertilized plot receiving phosphorus and potassium, but no nitrogen. These plots were selected because it was thought that yields from them would be a more sensitive measure of possible variation in nitrate content of the soil than would yields from unfertilized plots or from plots receiving so-called complete fertilizers.

The rotations involved in this discussion are: a three- and five-year one at Wooster (potatoes, wheat, clover) and (corn, oats, wheat, clover, timothy); two three-year rotations at Germantown (tobacco, wheat, clover) and (corn, wheat, clover); a three-year one at Carpenter (corn, wheat, clover); and a five-year one at Strongsville (corn, oats, wheat, clover, timothy).

The yield of wheat and rainfall records used in this paper are recorded in Tables 1 to 5 inclusive.

TABLE I.—*Annual yield of wheat per acre at the four farms.*

Year	Wooster Following potatoes Bus.	Wooster Following oats Bus.	Germantown Following tobacco Bus.	Germantown Following corn Bus.	Carpenter Following corn Bus.	Strongsville Following oats Bus.
1895	20.17	9.42				
1896	10.29	6.50				
1897	39.83	20.42				23.08[a]
1898	34.25	20.79				
1899	34.33	15.08				
1900	47.58	12.25				
1901	31.17	24.92				
1902	48.08	25.41				
1903	34.75	21.25				
1904	35.50	20.00	16.33			
1905	37.67	15.04	18.00	16.33	22.92	15.21
1906	47.50	32.29	21.71	18.72	19.83	14.79
1907	36.58	22.95	24.43	20.50	17.87	25.12
1908	47.17	29.54	22.67	15.00	15.58	23.96
1909	40.21	31.13	8.83	7.67	21.29	20.17
1910	38.62	18.21	35.16	21.92	11.08	15.79
1911	38.79	14.37	29.08	14.75	11.67	12.58
1912	16.08	10.16	00.00	00.00	22.00	00.00
1913	36.37	25.17	28.33	22.25	11.67	15.08
1914	31.50	35.08	42.17	26.00	22.33	24.58
1915	40.67	23.58	38.92	12.71	20.33	33.08
1916	35.25	24.54	30.08	15.04	11.58	30.17
1917	50.96	27.46	36.75	22.71	23.33	37.83
1918	30.39	19.96	24.42	14.21	15.00	22.83
1919	35.04	22.75	29.67	13.12	26.50	28.00
1920	30.83	11.12	00.00	00.00	11.50	18.00
1921	44.46	19.87	31.42	17.92	17.33	30.83
1922	34.58	23.29	18.00	12.79	5.00	27.83
1923	40.04	23.92	48.83	32.12	17.17	34.00

[a]Note: yields at Strongsville for the years 1898–1904 were omitted because of bad attacks of Hessian fly.

METHODS OF ACCUMULATING DATA

At each farm the yield data and rainfall data were treated alike. And the methods used in their preparation were the same at all farms. Therefore, a description of the methods employed at one farm will suffice for all.

At Wooster, for example, all the data, both yield and rainfall records, were first converted into percentages of their respective means. This was done by dividing the yield for each individual year, and the rainfall for each year, or part of a year, by their respective means. The purpose of this was to reduce both sets of values to a common denominator. This was desirable in order to obtain comparable figures with which to be able to plot both sets of values on like ordinates. The yield value and rainfall value for any given year, or part of a year, were then plotted on the same ordinate and the years were arranged in the order of decreasing rainfall.

In considering the relationship between yield and the annual rainfall, the years were arranged on the basis of the total precipitation

TABLE 2.—*Rainfall at Wooster. (inches).*

Year	Wheat year[a]	Group of months: Autumn[a]	Winter[a]	Early Spring	Late Spring	Individual months: Sept.[a]	Oct.[a]	Nov.[a]	Dec.[a]	Jan.	Feb.	Mar.	April	May	June
1895	25.97	9.19	7.53	3.67	5.58	4.25	2.53	2.41	3.15	3.97	.41	1.98	1.69	1.38	4.20
1896	31.19	9.28	7.51	7.01	7.39	3.92	1.15	4.21	3.51	1.73	2.27	3.67	3.34	3.41	3.98
1897	30.26	7.65	9.10	5.56	7.95	5.16	.71	1.78	3.04	3.42	2.64	2.81	2.75	4.97	2.98
1898	32.11	6.94	8.87	9.00	7.30	.29	.89	5.76	2.50	4.10	2.27	6.44	2.56	4.60	2.70
1899	29.39	10.57	7.22	5.23	6.37	2.15	4.28	4.14	2.29	3.29	1.64	3.95	1.28	4.42	1.95
1900	27.55	9.36	8.30	3.95	5.94	5.56	2.21	1.59	2.78	2.78	2.74	2.25	1.70	2.23	3.71
1901	27.05	8.59	3.77	5.55	9.14	2.19	2.10	4.30	.99	1.58	1.20	3.09	2.46	4.32	4.82
1902	25.64	8.05	4.93	4.54	8.12	5.64	.79	1.62	3.47	.63	.83	2.99	1.55	2.57	5.55
1903	32.05	7.63	11.30	7.84	5.28	3.49	1.52	2.62	4.07	3.54	3.69	3.29	4.55	1.59	3.69
1904	37.00	6.95	11.12	12.81	6.12	2.07	2.63	2.25	1.95	5.27	3.90	6.22	6.59	4.45	1.67
1905	28.00	3.54	5.87	5.12	13.47	2.27	.87	.40	2.68	1.83	1.36	2.61	2.51	5.97	7.50
1906	27.16	9.46	5.07	5.84	6.79	5.10	2.32	2.04	2.08	1.93	1.06	3.57	2.27	2.98	3.81
1907	38.68	11.10	11.80	8.49	7.29	5.16	3.55	2.39	3.79	6.92	1.09	5.80	2.69	3.48	3.81
1908	31.45	6.80	9.26	8.66	6.73	3.13	2.34	1.33	3.41	1.96	3.89	5.02	3.64	4.56	2.17
1909	31.70	3.04	11.22	6.94	10.50	.73	1.22	1.09	3.05	2.95	5.22	3.02	3.92	4.06	6.44
1910	30.25	6.80	12.25	3.76	7.44	1.73	2.16	2.91	2.55	5.29	4.41	.54	3.22	4.87	2.57
1911	32.06	10.19	8.67	6.97	6.23	2.59	5.24	2.36	2.29	4.13	2.25	3.26	3.71	2.45	3.78
1912	40.11	14.48	8.42	9.35	7.86	6.53	5.45	2.50	4.54	2.30	1.58	3.77	5.58	5.65	2.21
1913	40.53	8.38	12.64	15.50	4.01	4.41	2.18	1.79	2.35	7.86	2.43	11.84	3.66	3.04	.97
1914	32.12	10.64	5.51	6.70	9.31	3.70	3.17	3.77	1.92	1.64	1.95	2.37	4.33	2.98	6.33
1915	27.61	7.88	8.03	2.58	9.12	2.87	3.33	1.68	3.67	2.32	2.04	1.17	1.41	2.80	6.32
1916	36.07	10.40	10.03	7.64	8.00	4.90	2.85	2.65	3.32	4.98	1.73	4.72	2.92	2.95	5.05
1917	26.97	5.68	6.85	5.66	8.78	1.07	2.03	2.58	2.43	3.12	1.30	3.66	2.00	3.94	4.84
1918	25.13	6.68	6.69	4.97	6.79	1.48	4.76	.44	1.64	2.66	2.39	2.01	2.96	4.88	1.91
1919	28.66	7.52	5.87	6.48	8.79	3.27	2.82	1.43	3.71	1.20	.96	3.82	2.66	6.17	2.62
1920	32.84	10.17	5.07	7.75	9.85	1.46	6.00	2.71	1.69	2.47	.91	2.08	5.67	1.59	8.26
1921	28.94	5.87	6.34	10.54	6.19	2.12	1.30	2.45	1.93	2.00	2.41	6.26	4.28	3.42	2.77
1922	37.01	13.63	6.34	8.39	8.65	6.35	1.58	5.70	2.36	1.71	2.27	3.80	4.59	5.61	3.04
1923	24.38	4.26	9.25	4.77	6.10	.89	1.67	1.70	3.13	4.33	1.79	2.49	2.28	4.11	1.99

[a]Rainfall for September to December, inclusive is that of previous year.

TABLE 3.—*Rainfall at Germantown.* (*inches*)

	Group of months					Individual months									
Year	Wheat Year[a]	Autumn[a]	Winter[a]	Early Spring	Late Spring	Sept.[a]	Oct.[a]	Nov.[a]	Dec.[a]	Jan.	Feb.	Mar.	April	May	June
1904	27.59	4.28	7.72	8.92	6.67	0.73	1.62	1.93	2.24	3.40	2.08	6.38	2.54	3.65	3.02
1905	28.68	3.12	8.59	6.42	10.70	1.07	1.70	.35	4.93	1.31	2.30	2.97	3.45	7.70	3.00
1906	30.20	9.90	7.27	8.81	4.22	3.56	4.10	2.24	3.28	2.92	1.07	6.93	1.88	1.34	2.88
1907	34.95	7.75	11.86	8.49	6.85	2.30	1.65	3.80	4.32	7.22	.32	6.23	2.26	3.20	3.65
1908	38.12	11.81	11.66	8.77	5.89	5.64	2.92	3.25	3.22	2.11	6.33	4.24	4.53	4.47	1.42
1909	36.27	2.32	12.39	7.65	12.91	.35	.27	1.70	1.31	3.41	7.67	2.07	5.58	6.98	5.93
1910	25.85	5.97	11.25	1.97	6.66	.89	3.13	1.95	4.00	3.00	4.25	.10	1.87	5.08	1.58
1911	34.87	12.52	9.31	9.01	4.03	3.96	7.60	.96	2.85	5.00	1.46	3.00	6.01	1.36	2.67
1912	37.95	12.70	8.72	10.80	5.73	5.16	4.48	3.06	3.81	3.23	1.68	4.29	6.51	3.49	2.24
1913	37.35	6.01	13.75	12.57	5.02	2.50	2.79	.72	3.30	8.40	2.05	7.32	5.25	2.62	2.40
1914	26.42	9.59	7.25	5.52	9.06	2.33	2.56	4.80	.88	2.62	3.75	3.05	2.47	1.43	2.63
1915	23.29	4.40	7.42	2.88	8.59	.18	2.19	2.03	2.72	2.95	1.75	1.34	1.54	5.58	3.01
1916	35.47	10.06	11.28	5.33	8.80	5.62	2.12	2.32	3.53	6.34	1.41	3.20	2.13	3.58	5.22
1917	31.17	6.60	8.51	7.58	8.48	2.78	1.91	1.91	2.80	4.15	1.56	4.31	3.27	4.11	4.37
1918	27.16	6.09	8.16	5.22	7.69	1.82	3.77	.50	1.95	4.07	2.14	1.71	3.51	4.18	3.51
1919	28.24	8.12	5.08	9.01	6.03	4.60	1.86	1.66	3.32	1.08	.68	4.85	4.16	4.53	1.50
1920	37.90	12.92	5.55	11.05	8.38	1.02	7.93	3.97	2.30	1.44	1.81	3.48	7.57	2.95	5.43
1921	29.84	7.58	7.25	12.07	2.94	3.01	1.38	3.19	2.05	2.79	2.41	8.06	4.01	1.69	1.25
1922	37.64	13.91	5.05	11.42	7.26	4.48	2.66	6.77	1.85	1.46	1.74	6.39	5.03	5.94	1.32
1923	29.28	6.57	10.75	5.61	6.35	2.71	1.92	1.94	4.49	4.00	2.26	3.18	2.43	3.26	3.09

[a]Rainfall for September to December, inclusive is that of previous year.

TABLE 4.—*Rainfall at Carpenter. (inches)*

	Group of Months					Individual Months									
Year	Wheat Year[a]	Autumn[a]	Winter[a]	Early Spring	Late Spring	Sept.[a]	Oct.[a]	Nov.[a]	Dec.[a]	Jan.	Feb.	March	April	May	June
1905	28.03	3.36	5.77	6.77	12.13	2.08	1.10	.18	3.40	1.02	1.35	4.07	2.70	7.02	5.11
1906	30.65	8.67	8.94	5.25	7.79	1.02	5.20	2.45	3.51	3.58	1.85	3.82	1.43	1.40	6.39
1907	41.70	9.32	14.72	9.70	7.96	3.24	2.58	3.50	3.50	8.94	2.28	6.13	3.57	3.47	4.49
1908	34.09	7.46	7.40	12.95	6.28	2.94	2.38	2.14	1.72	1.37	4.31	7.80	5.15	3.36	2.92
1909	32.39	2.70	10.90	6.87	11.92	.48	.85	1.37	2.13	3.05	5.72	2.77	4.10	4.29	7.63
1910	25.72	3.88	13.15	3.43	5.26	.86	2.12	.90	2.05	6.40	4.70	.20	3.23	2.91	2.35
1911	29.89	4.09	11.44	6.16	8.20	.99	1.68	1.42	2.80	5.56	3.08	2.26	3.90	2.06	6.14
1912	32.24	11.06	7.93	7.43	5.82	5.18	3.68	2.20	4.01	1.48	2.44	3.39	4.04	2.90	2.92
1913	26.51	4.69	10.85	4.45	6.52	2.51	1.80	.38	2.09	6.78	1.98	1.71	2.74	4.23	2.29
1914	22.30	7.30	5.58	4.56	4.86	2.07	2.89	2.34	2.36	1.17	2.05	1.72	2.84	2.33	2.53
1915	25.26	5.13	8.51	2.27	9.35	1.07	2.98	1.08	4.65	2.91	.95	1.05	1.22	4.95	4.40
1916	36.11	8.95	13.09	5.78	8.29	3.64	1.96	3.35	4.85	4.91	3.33	3.83	1.95	4.72	3.57
1917	34.46	5.57	9.94	10.06	8.89	1.89	2.22	1.46	3.29	6.28	1.37	6.19	3.87	3.61	5.28
1918	29.16	6.88	6.01	8.61	7.66	1.52	4.71	.65	.65	2.37	2.99	4.07	4.54	2.81	4.85
1919	30.29	7.39	9.21	5.23	8.46	1.55	3.23	2.61	4.90	2.78	1.53	3.02	2.21	5.74	2.72
1920	37.44	11.39	10.35	9.50	6.20	1.20	5.34	4.85	4.08	4.27	2.00	3.54	5.96	2.42	3.78
1921	26.56	6.57	6.91	6.76	6.35	2.92	1.87	1.78	1.81	3.38	1.72	4.89	1.87	4.89	1.46
1922	38.11	14.22	7.94	10.66	5.29	6.62	1.70	5.90	4.41	1.92	1.61	6.78	3.88	2.77	2.52
1923	29.62	7.03	10.23	6.53	5.83	3.20	2.67	1.16	3.63	4.02	2.58	3.35	3.18	2.91	2.92

[a]Rainfall for September to December, inclusive is that of previous year.

TABLE 5.—*Rainfall at Strongsville.* (*inches*)

Year	Group of Months					Individual Months									
	Wheat Year[a]	Autumn[a]	Winter[a]	Early Spring	Late Spring	Sept.[a]	Oct.[a]	Nov.[a]	Dec.[a]	Jan.	Feb.	March	April	May	June
1897	29.19	8.66	5.49	7.17	7.87	5.97	.73	1.96	2.96	.91	1.62	3.29	3.88	5.99	1.88
1905	27.29	4.43	9.08	7.21	6.56	2.73	1.20	.50	3.87	2.48	2.73	3.24	3.97	4.38	2.18
1906	28.15	9.37	5.75	7.35	5.68	3.50	2.95	2.92	1.66	2.03	2.06	5.42	1.93	1.01	4.67
1907	46.74	16.51	11.53	10.21	8.49	6.70	5.04	4.77	5.12	5.21	1.20	6.30	3.01	3.54	4.95
1908	33.28	9.61	9.86	8.82	4.99	3.43	4.38	1.80	3.59	2.27	4.00	5.35	3.47	2.82	2.17
1909	24.03	3.68	6.94	6.08	7.33	1.00	1.60	1.08	1.90	2.48	2.56	2.59	3.49	4.13	3.20
1910	26.70	8.11	8.31	4.73	5.55	2.71	2.60	2.80	1.30	4.80	2.21	1.10	3.63	3.05	2.50
1911	29.28	12.73	7.94	4.88	3.75	4.85	3.90	3.98	2.99	3.77	1.16	1.85	3.03	1.95	1.80
1912	29.84	12.01	12.32	8.03	5.42	5.33	3.85	2.83	1.51	1.38	1.49	2.91	5.12	3.62	1.80
1913	29.61	6.94	7.64	11.38	3.45	4.34	2.40	.20	1.89	4.50	1.45	9.30	2.08	2.15	1.30
1914	30.58	9.50	5.03	7.35	8.70	3.30	3.59	2.61	1.13	2.00	1.90	2.40	4.95	5.30	3.40
1915	21.61	4.88	8.80	2.22	5.71	.40	2.83	1.65	5.56	1.79	1.45	1.07	1.15	2.25	3.46
1916	22.54	6.22	5.10	3.48	7.74	3.86	.95	1.41	1.52	3.10	.48	1.26	2.22	2.72	5.02
1917	26.26	7.98	4.51	6.30	7.47	3.60	2.37	2.01	1.19	1.92	1.40	2.88	3.42	4.83	2.64
1918	23.83	7.19	4.15	3.59	8.90	2.11	4.21	.87	1.47	1.64	1.04	1.35	2.24	4.87	4.03
1919	26.22	8.21	6.00	5.89	6.12	4.16	1.85	2.20	2.99	1.62	1.39	2.16	3.73	4.28	1.84
1920	33.49	14.58	4.88	5.64	6.89	2.44	6.93	5.21	1.78	1.60	1.50	.50	5.14	1.71	5.18
1921	24.25	8.47	4.47	7.01	4.30	.99	2.95	4.53	1.28	1.64	1.55	4.24	2.77	2.18	2.12
1922	26.43	9.77	3.81	6.89	5.96	5.03	3.20	1.54	.38	2.45	.98	3.34	3.55	3.36	2.60
1923	24.85	6.57	7.14	4.50	6.64	1.75	3.32	1.50	2.79	3.24	1.11	2.34	2.16	3.68	2.96

[a]Rainfall for September to December, inclusive is that of previous year.

for the wheat-year, that is, for the months of September to June inclusive. In considering the relationship between yield and rainfall for various parts of the year, the years were arranged first, on the basis of the rainfall for the seasonal groups of months, as the autumn group, winter group, etc.; and second, on the basis of the rainfall for individual months, as for September, October, November, etc.

After plotting the figures for yield and for rainfall, there was fitted into each set of values a straight line, by the method of least squares. The straight lines only are shown in the figures which accompany this article.

RESULTS OF THE STUDY

The relationship between yield and rainfall, the latter for the entire wheat-year, is shown for Wooster, Germantown, Carpenter and Strongsville in Figures 1, 2, 3 and 4 respectively. These figures show that at all four places, a decrease in rainfall is accompanied by an increase in yield.

In this connection, it is of interest to note the relationship which is shown in a few of those years in which the yields have been conspicuously high. Take the yield of any given plot, as for example, that of Plot 8 in the potato rotation at Wooster. By going back over the yields of this plot for the last 29 years, it is found that the highest three yields were obtained in the years 1900, 1902 and 1917. The rainfall month by month for each of these three wheat-years, also the normal are shown in Figure 5. (Normal rainfall equals the average for the period of time for which records are available at any given farm. The length of these periods ranges from 19 to 35 years.) In no one of the three years did the monthly rainfall equal the normal more than three times.

The rainfall relations for the three years of the most outstanding wheat yields at Germantown and at Strongsville are shown in Figures 6 and 7 respectively.

At Carpenter, there have been no outstanding yields; hence, no graphs are shown for that place. Lack of such yields at that station is probably due to poor fertility conditions. Land in that section of the state is relatively thin and, besides, the wheat on that farm follows corn.

The question now arises: In what part of the year, if any, is subnormal rainfall most beneficial?

Some evidence on this point is given in Table 6 which shows the relationship between yield and rainfall for various groups of months at Wooster, Germantown, Carpenter and Strongsville. In this table these relationships are expressed by means of the straight line equa-

tions rather than by the straight lines themselves. This was done in order to economize space.

The equations presented are the ones derived from the yield values only and the point about them which is of most significance in this connection is the sign of the x value. In interpreting these equations, it must be remembered that they were derived by first arranging the years in the order of decreasing rainfall. The equations, therefore, indicate that a decrease in rainfall is accompanied by an increase or a decrease in yield according as the sign of the x value is plus or minus.

Thus, the equations indicate that during the autumn months, a decrease in rainfall is accompanied by an increase in yield of wheat at all four stations, because in all cases the sign of the x value is plus, or positive. In the winter months, a decrease in rainfall is accompanied by a decrease in yield at Wooster and Germantown and by an increase in yield at Carpenter and Strongsville, because the sign of the x value in the two former is minus, or negative, and in the two latter, it is plus, or positive. In early spring, the relationship is positive throughout. In late spring, it is equally divided, being positive at Wooster and Germantown, and negative at Carpenter and Strongsville.

From Table 6, therefore, it appears that in the fall and early spring, moderately dry weather is more beneficial than it is in the winter or late spring, because in the former two groups of months, there is a positive relationship at all four places; while in the latter two groups the number of positive and negative relationships is equally divided, thus indicating an indifference of wheat toward rainfall at these particular periods of the year.

Considering the relative importance of subnormal rainfall in each month separately, there are two months only, November and April, in which there is a positive correlation at all four localities. This is shown in Table 7, where the calculations are based on the rainfall for individual months. From this Table, it is possible also to make a more critical analysis of the material embodied in the groups shown in Table 6. For example, it may be seen that there is a positive relationship ten times out of a possible twelve in the group of autumn months; six times out of a possible twelve in the group of winter months; seven times out of a possible eight in the two early spring months and three times out of a possible eight in the months of May and June. And only one of these is in the month of June.

If the hypothesis assumed in the introductory paragraph of this paper be true, that is, if nitrate nitrogen is the key to the apparent relationship between wheat yield and rainfall under Ohio conditions,

TABLE 6.—*Relationship between yield of wheat and rainfall for various groups of months.*

Group of Months	Station: Wooster	Germantown	Carpenter	Strongsville
Autumn (September, October, November)	y = 84.039+1.140x	y = 79.996+2.106x	y = 88.501+1.278x	y = 80.292+2.073x
Winter (December, January, February)	y = 100.852—0.061x	y = 102.896—0.305x	y = 82.521+1.943x	y = 71.176+3.033x
Early spring (March, April)	y = 36.119+0.456x	y = 61.269+4.077x	y = 93.099+0.768x	y = 76.065+2.517x
Late spring (May, June)	y = 99.173+0.059x	y = 96.994+0.317x	y = 122.860—2.539x	y = 123.711—2.497x

TABLE 7.—*Relationship between yield of wheat and rainfall for individual months.*

Month	Station: Wooster	Germantown	Carpenter	Strongsville
September	y = 94.442+0.397x	y = 101.531—1.603x	y = 91.288+0.969x	y = 80.622+2.037x
October	y = 90.392+0.686x	y = 82.967+1.793x	y = 112.752—1.416x	y = 87.343+1.331x
November	y = 82.928+1.219x	y = 90.847+0.963x	y = 92.413+0.844x	y = 89.584+1.095x
December	y = 94.040+0.426x	y = 109.570—1.009x	y = 104.949—0.549x	y = 97.346+0.278x
January	y = 101.821—0.130x	y = 117.793—1.873x	y = 81.582+2.048x	y = 99.837+0.015x
February	y = 106.557—0.468x	y = 103.819—0.402x	y = 82.717+1.921x	y = 78.431+2.268x
March	y = 101.239—0.088x	y = 87.315+1.335x	y = 95.543+0.496x	y = 92.234+0.816x
April	y = 87.562+0.889x	y = 48.583+5.412x	y = 85.546+1.608x	y = 76.206+2.503x
May	y = 96.896+0.222x	y = 89.373+1.118x	y = 120.353—2.260x	y = 113.589—1.432x
June	y = 101.821—0.130x	y = 88.958+1.162x	y = 115.734—1.747x	y = 121.140—2.227x

then it is of interest to compare the relationship between rainfall and two sets of wheat yields both obtained on the same farm but each following a different crop, one of which is known to be more favorable than the other to the accumulation of nitrates. It is possible to make a comparison of this kind at both Wooster and Germantown. At Wooster, for example, there are available two sets of wheat yields; one, where the wheat follows potatoes; the other, where it follows oats. Likewise, at Germantown, there are two sets of wheat yields; one following tobacco, the other following corn. Experimental evidence indicates that potatoes and tobacco are more favorable to an accumulation of nitrates than are corn and oats (5). The relationships at Wooster are shown in Figure 8, and at Germantown in Figure 9. At both places the graphs show that the higher relationships are found where the wheat follows the crop which is the more favorable for nitrate accumulation; namely, potatoes at Wooster and tobacco at Germantown. This result is as would be expected if nitrates are a factor in the relationship between wheat yield and rainfall.

It is probable that an abundance of nitrates tends to increase the degree of tillering, and, within limits, an increase in tillering is accompanied with an increase in yield. That the latter is true is shown in Table 8, where are given the number of culms and the yield per acre on certain plots for three different seasons at Wooster.

TABLE 8.—*Number of culms and yield per acre.*

Number of culms per acre			Yield per acre—bushels		
1921	1922	1923	1921	1922	1923
1,789,740	1,898,787	2,195,610	34.49	36.77	38.17

The yield in each case is based on the average of five tenth-acre plots. The number of culms per acre was estimated from counts of stubble made on the same five tenth-acre plots. On each plot, the number of stubble in ten areas, each one yard square, was counted. From the average of these ten counts, the total number of culms per plot was estimated. The stand in five plots was thus estimated, and on the basis of the average of these was calculated the number of culms per acre.

DISCUSSION OF RESULTS OF THIS STUDY

The facts herein presented indicate that wheat yields in Ohio are, as a rule, depressed by too much rainfall and that the exceptionally high yields, which are obtained now and then represent what wheat could and probably would do every year, barring the interference of other factors, providing the rainfall were a little less.

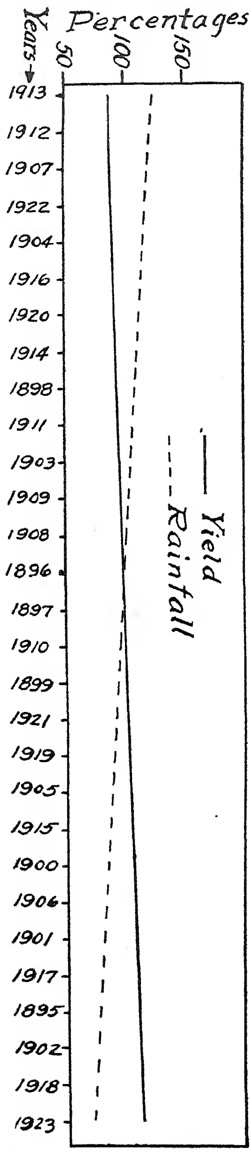

FIG. 1. Graphs of wheat yields (bushels) and rainfall (inches) both expressed in percentages of their respective means. Wooster, 29-year records.

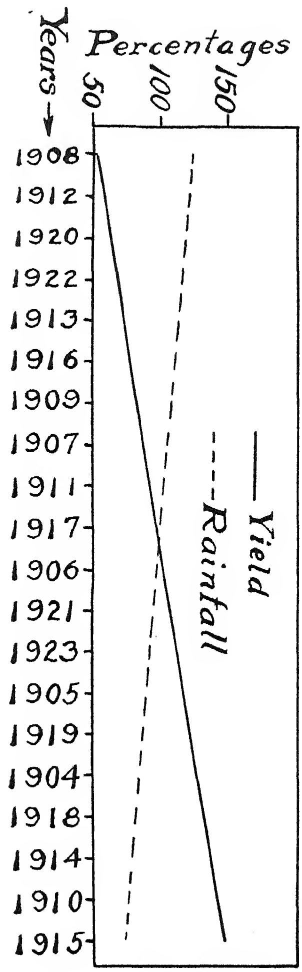

FIG. 2. Graphs of wheat yields (bushels) and rainfall (inches) both expressed in percentages of their respective means. Germantown, 20-year records.

In this connection it is of interest to note that Knight (2) doing irrigation work in Nevada found that applications of water in excess of 28 inches reduced the yield of wheat.

Widtsoe and Stewart (6) doing irrigation work in Utah write: "At every period of growth the percentage of heads increased inversely with the amount of water applied. Considering the plant as a whole the tendency at every stage of growth was for the proportion of heads

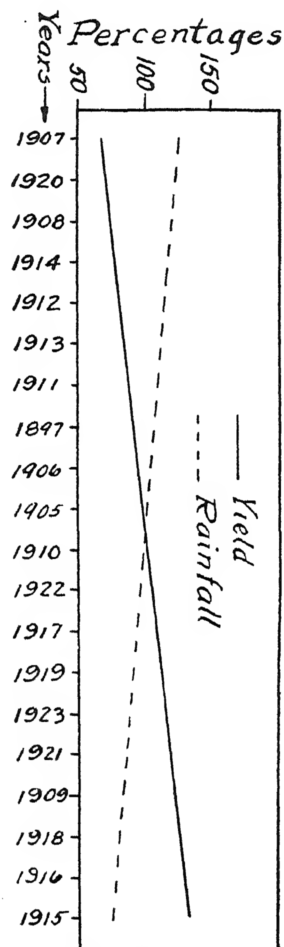

FIG. 3. Graphs of wheat yields (bushels) and rainfall (inches) both expressed in percentages of their respective means. Carpenter, 19-year records.

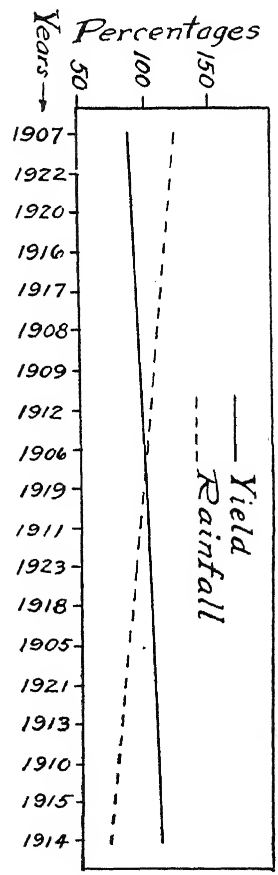

FIG. 4. Graphs of wheat yields (bushels) and rainfall (inches) both expressed in percentages of their respective means. Strongsville, 20-year records.

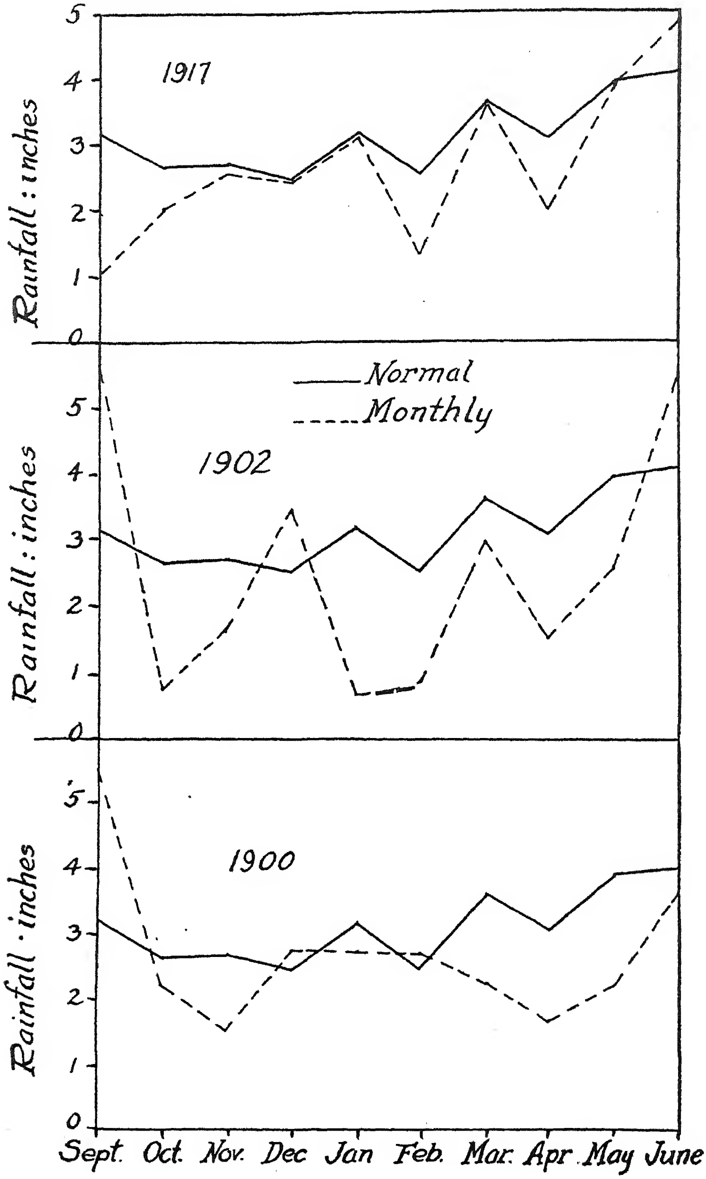

FIG. 5. Graphs of normal (35-year average) and of monthly rainfall at Wooster for the wheat-years 1900, 1902 and 1917.

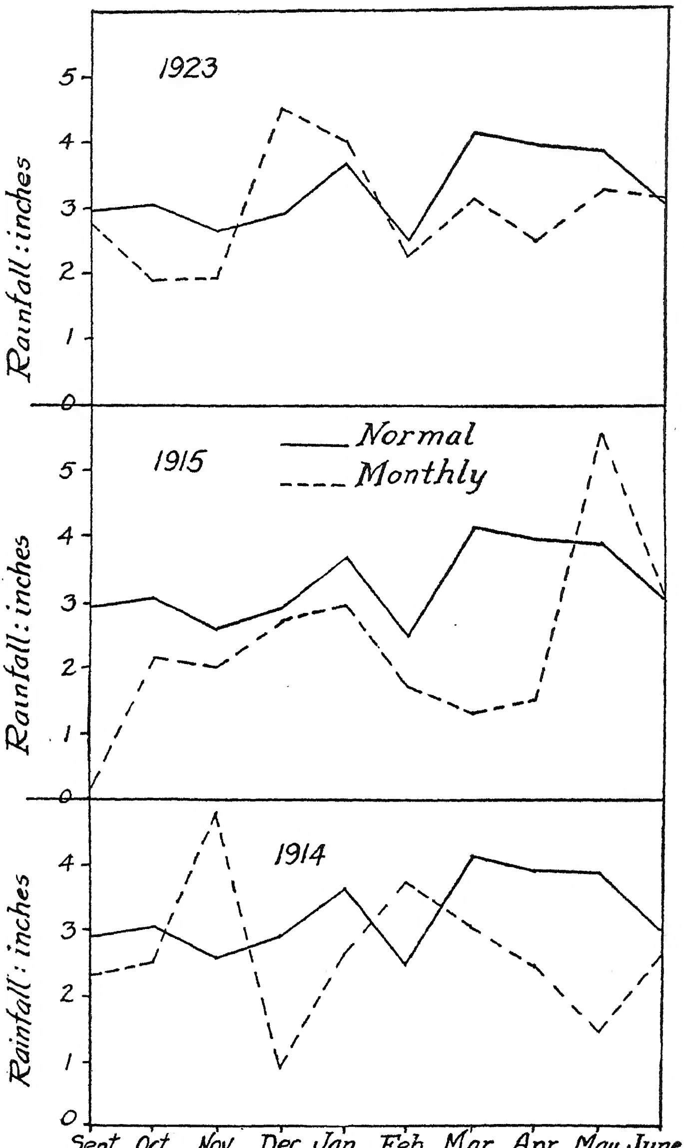

FIG. 6. Graphs of normal (20-year average) and of monthly rainfall at Germantown for the wheat-years 1914, 1915 and 1923.

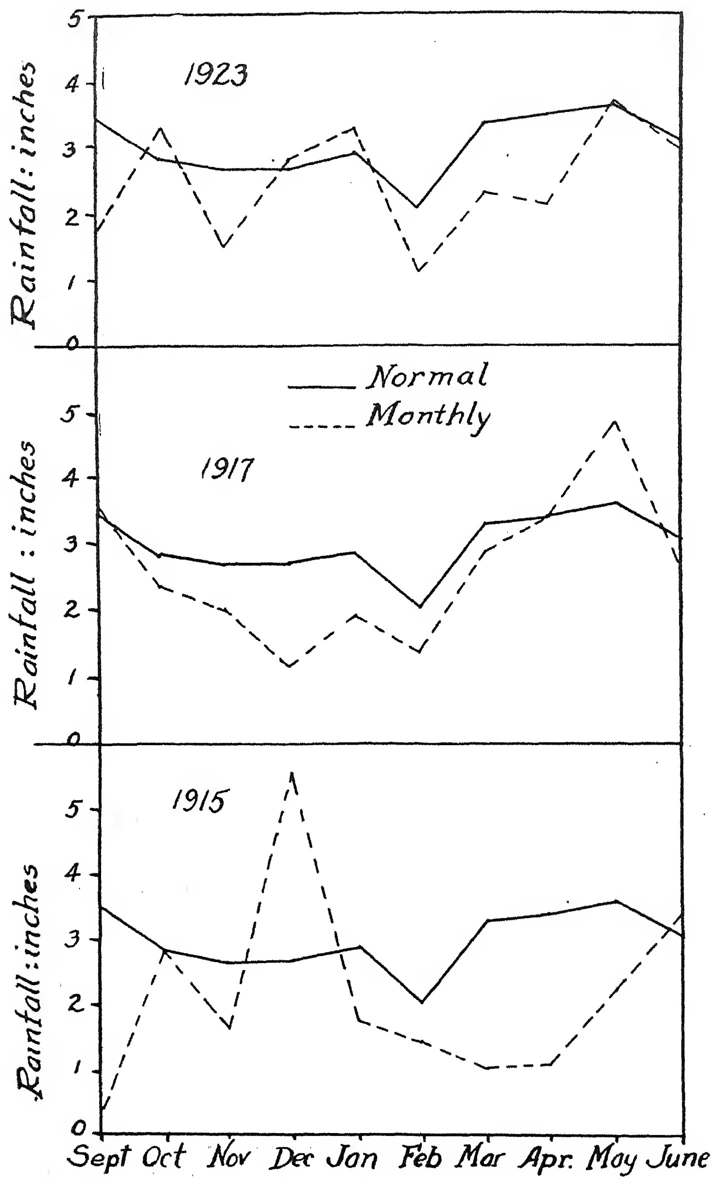

FIG. 7. Graphs of normal (20-year average) and of monthly rainfall at Strongsville for the wheat-years 1915, 1917 and 1923.

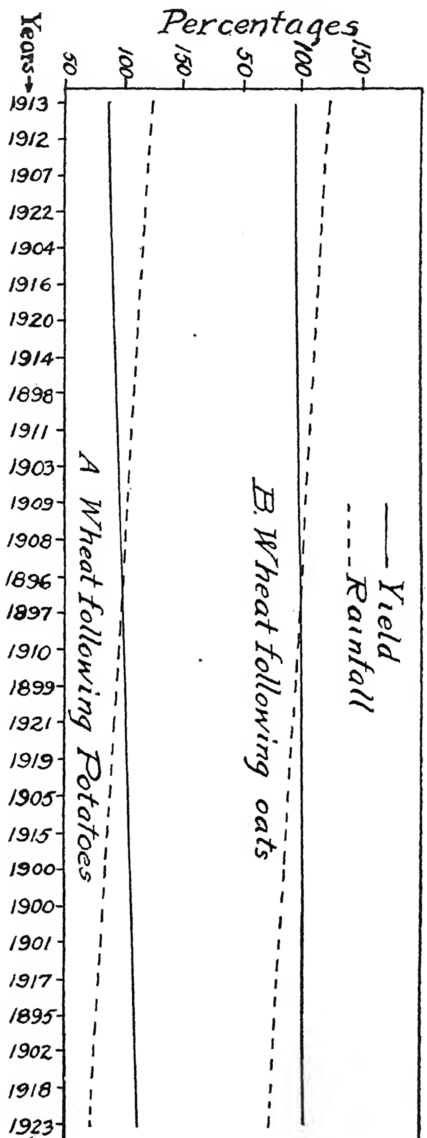

FIG. 8. Graphs of wheat yields (bushels) and rainfall (inches) both expressed in percentages of their respective means. Wooster, 29-year records.

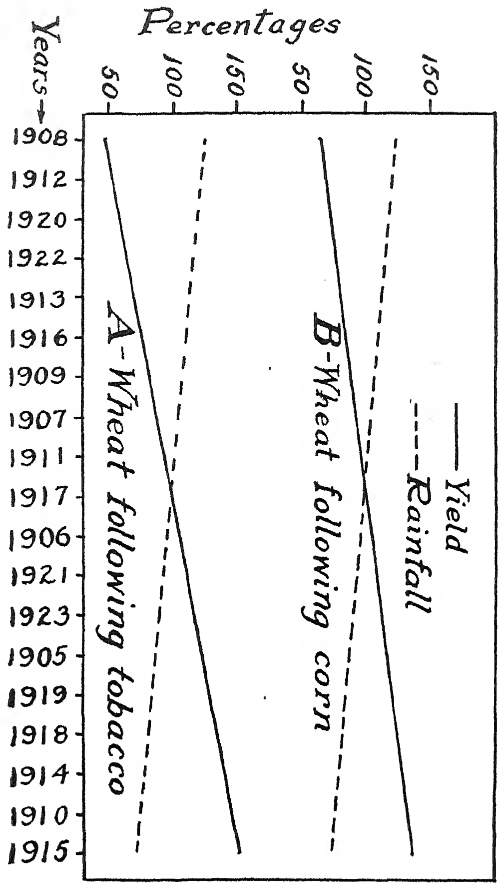

FIG. 9. Graphs of wheat yields (bushels) and rainfall (inches) both expressed in percentages of their respective means. Germantown, 19-year records.

to increase and the stalks and leaves to decrease as the amount of irrigation water decreased."

Also it is of moment to note the amount of rainfall in the great wheat-producing regions of the world. According to Finch and Baker (1), there are eight such regions and in most of them, they say, the average annual rainfall is less than 30 inches. In Ohio, the average annual rainfall is approximately 38 inches.

That moderately dry weather and consequent high nitrate content of the soil are most beneficial in the fall and early spring is to be expected; because, according to Weaver, *et al* (4), these are periods in which root growth and tillering take place rapidly. These investi-

gators found that, under Nebraska conditions, root growth continued until the middle of December and at that time the soil was well occupied with roots to a depth of three feet, some of which had penetrated to a depth of four feet. They found that tillering began 15 days after planting and continued to the middle of December. Both root growth and tillering were resumed in the spring about the middle of March.

In late spring, wheat appears to be tolerant of, or perhaps to need, more water. This may be due to the fact that, in this stage, the function of the wheat plant is somewhat changed. In the later weeks of its life, the wheat plant is no longer taking up much material either from the soil or the air; its chief function being to translocate material from the leaves and stems to the seeds.

In the winter period, wheat appears to be more or less indifferent to rainfall. However, it is probable that moderately dry weather is preferable even at this season, especially in years of extremely cold weather, because, according to McCool and Miller (3), a decrease in soil moisture is accompanied by a lowering of the freezing point of root-cell sap. This, of course, would make for winter hardiness.

SUMMARY

The statistical data reported herein indicate that in Ohio:

A decrease in rainfall is accompanied by an increase in yield of wheat;

Subnormal rainfall is more beneficial in the autumn and early spring, than in the winter or late spring;

November and April are the two individual months in which subnormal rainfall appears to be most beneficial;

Wheat yields are probably depressed in most years by too much rainfall.

LITERATURE CITED

1. Finch, V. C., and Baker, O. E. Geography of the World's Agriculture, 1917.
2. Knight, C. S. Irrigation of wheat in Nevada. Nevada Agr. Exp. Sta. Bul. 92.
3. McCool, M. M., and Miller, C. E. The water-content of the soil and the composition and concentration of the soil solution as indicated by the freezing-point lowerings of the roots and tops of plants. *In* Soil Sci., 3:113–138. 1917.
4. Weaver, J. E., Kramer, Jos., and Reed, Maud. Development of root and shoot of winter wheat under field environment. Ecology, 5:26–50. 1924.
5. Welton, F. A., and Morris, V. H. Yields of wheat following potatoes and the relation of nitrates in the soil to these. *In* Jour. Am. Soc. Agron. 16: 519–534. 1924.
6. Widtsoe, J. A., and Stewart, R. The effect of irrigation on the growth and composition of plants at different periods of development. Utah Agr. Exp. Sta. Bul. 119. 1912.

THE EFFECT IN POT CULTURE OF GREEN MANURE IN DIFFERENT STAGES OF GROWTH AND DECOMPOSITION, ON THE SUBSEQUENT CROP[1]

Burt L. Hartwell and F. R. Pember[2]

In attempting to supply organic matter by green manure instead of by stable manure, the market gardener must depend on the liberal use of fertilizer to provide the nutrient needs of the crops. Because the fertilizer expense is relatively less important in comparison with the cost of the other items connected with his intensive operations, he can afford to be quite profligate in his use of plant food, if desired results are thereby attainable.

Provided ample water and fertilizer are at hand, the question arises as to how important are the stage of growth and the degree of decomposition of the material used for green manure.

Of interest in this connection are a few pot experiments, the results of which will now be given in brief.

Wagner pots, 8 inches in diameter and height, and silt loam soil from the experimental fields were used in each case. The general procedure was to grow the green manure crop in the pots, using liberal fertilizer, and at different stages of growth, after cutting the crop into one-inch or smaller pieces, to place the material in a layer under about four inches of the soil, somewhat as is done in plowing under a green-manure crop. At a subsequent date, the top soil was again fertilized, prior to planting cos lettuce, or romaine, as a crop to demonstrate the effect, if any, of the green manure in different conditions.

In some cases, hydrated lime at the rate of one ton per acre was mixed with the layer of green manure, and in other cases this was omitted; but, inasmuch as it exerted practically no influence, it is only necessary to focus attention on the fertilization, for it will be seen later that, in the experiment of 1922, the fertilizer was supplied so liberally that the condition of the green manure was of practically no importance.

In 1920 and 1921, oats were grown for green manure, and the fertilization per pot was as follows:

	Grams
Acid phosphate (2930 pounds per acre)	10.0
Sulphate of potash,	3.0
Nitrate of soda,	2.0

[1]Contribution 311 of the Agricultural Experiment Station of the Rhode Island State College, Kingston. Received for publication, September 29, 1924.

[2]Director and Agronomist, and former Associate in Glasshouse Experiments, respectively.

It was considered that this liberal application would give maximum growth of the oats without leaving the soil in a depleted condition and that the acid phosphate would inactivate any soil aluminum which might otherwise be toxic to the sensitive lettuce.

Furthermore, the cos lettuce was given per pot, only at the time of planting, 1.8 grams acid phosphate, 0.4 gram sulphate of potash and 1.0 gram nitrate of soda.

In 1920, the green leaves of lettuce, planted the last of July and harvested September 28, averaged per pot 273 grams in weight after 70 grams of green oats 18 inches tall had been turned under June 29; 171 grams, after 139 grams of oats beginning to head had been turned under July 12; and 95 grams, after 152 grams of oats in the milk stage had been turned under July 27.

Similarly, in 1921, with new soil, the green leaves of lettuce planted July 19 and harvested September 19 averaged per pot 294 grams after 129 grams of oats 15 to 20 inches tall turned under June 24; and 168 grams, after 160 grams of oats in the milk stage turned under July 14. Again, lettuce planted July 30 and harvested October 4 averaged 134 grams, after 160 grams of oats in the milk stage turned under July 14; and 89 grams, after yellowed oats 40 inches tall turned under July 27.

Also in 1921, under the same conditions as the lettuce, carrot roots, planted July 26 and harvested October 31, averaged 159 grams, after 130 grams of oats turned under July 1; and 110 grams, after 157 grams of oats turned under July 19. Again, when planted August 2, carrots averaged 115 grams, after oats turned under in the milk stage July 19; and 87 grams, after yellowed oats turned under July 29.

In spite of the equivalent per acre of about 5200 pounds of 2–9–8 fertilizer for the oats and about 1030 pounds of 5–8–5 fertilizer for the following lettuce and carrots, it is evident that oats planted at a given time affected the following crops the most favorably if they were turned under when young and subjected to decomposition; whereas their influence was the least advantageous, or the most objectionable, when they were turned under at the approach of maturity and allowed no opportunity to decompose before the following crop was planted.

This is the usual experience; and because the moisture factor was eliminated in this instance, attention was directed to the fertilizer factor as concerns particularly the nitrogen compounds. One prominent explanation of the retarding effect of strawy material is that it does not promote or perhaps even retards the accumulation of nitrates.

In the next experiment, it will be seen that the variation in the effect of the green manure depending on its stage of growth and decomposition was prevented by the prodigal use of fertilizer during the growth of lettuce.

In 1922, again with new soil, buckwheat was the green manure crop used, the fertilization of which was the same as for the oats. Three sets of duplicate pots were planted June 6, 22 and July 8, and the buckwheat turned under, in all cases with 14.5 grams of added hydrated lime, on July 10, 26 and August 11, respectively, when all were in bloom, about 26 inches tall, and averaging 212 grams (31 tons per acre) of green material per pot. The nearly moisture-free cos lettuce, which was planted on the uniform date of August 12 and harvested on November 8, averaged respectively 25, 26 and 27 grams per pot. This shows that such decomposition of the buckwheat used for green manure at blooming time as took place even between July 10 and August 11 had practically no effect on the succeeding crop.

It now remains to show the effect of buckwheat turned under when some of the grain hulls had become brown and the plants were 39 inches tall and averaged 270 grams per pot. One lot of such buckwheat was planted June 6 and turned under July 26, and the other planted June 22 and turned under August 11. The cos lettuce was planted, harvested and dried as before. It averaged respectively 29 and 24 grams per pot. Pots in which no buckwheat was grown, but otherwise strictly comparable, averaged 28 grams of the lettuce.

Practically, it may be said that none of the buckwheat affected the lettuce, probably because of the fertilization of the latter, which will now be considered.

At the time of planting, on August 12, there were mixed with the upper four inches of soil, 5 grams acid phosphate, 1 gram sulphate of potash and 1 gram nitrate of soda. On September 30, differences were appearing in the lettuce, and to determine whether these differences could be eliminated the following fertilizer was added per pot in connection with watering, namely: 5 grams acid phosphate, 4 grams sulphate of potash, and 3 grams nitrate of soda. The result was that the differences gradually disappeared.

In the experiments of 1920 and 1921, the lettuce fertilizer was about equivalent to 1030 pounds of a 5–8–5 fertilizer per acre and the *maximum* growth of green lettuce was 294 grams per pot. In 1922, the *average of the lots*, all of which were similar, was 307 grams; and the total fertilizer given to the lettuce was equivalent to about 7,000 pounds of a 3–6–10.

In the field, there has been practically no difference during three seasons in the growth of celery set out in the middle of July, using the equivalent of about a ton of 5-8-5 fertilizer, whether, early in June, fully headed rye or slightly headed wheat, or a month later, oats, had been turned under for green manure. Larger yields of celery have been obtained thus far, however, with stable manure than with green manures.

It may prove difficult to apply economically the large amount of fertilizer necessary to secure to a rotation the benefits of the organic matter in an abundant green manure crop, and also to obtain a satisfactory yield of the crop immediately following the green manure. The difficulties will increase when a lack of rainfall lessens the opportunity for additional fertilizer applications.

WILLIAM D. HURD

It is with the deepest regret that we announce the sudden and untimely death of Professor William D. Hurd at his home in Washington, D. C., Friday, August 22nd.

Professor Hurd was a native of Michigan, having graduated from the Agricultural College at East Lansing in 1899. Four years later he became Professor of Agriculture in the University of Maine. He was Dean of the Agricultural College of the latter institution from 1906 to 1909, and from 1909 to 1919 he was director of the extension service in the Massachusetts Agricultural College.

In 1919 he became Western Manager of the Soil Improvement Committee of the National Fertilizer Association, and he has been Director of this organization since 1920. During the war he was a special assistant to the Secretary of Agriculture.

During the past five years Director Hurd labored unceasingly in an effort to bring the fertilizer industry and the agricultural workers of the country to a better understanding of their mutual problems. He always thought of the fertilizer industry in terms of agriculture as a whole, and he believed thoroughly that neither could prosper permanently unless the other prospered accordingly. He was in many respects an idealist, and progressive always. His leadership, however, was of a practical kind that produces results which can be measured.

Professor Hurd was an active worker in a number of scientific and civic organizations. He was a Fellow of the American Association for the Advancement of Science, a member of the American Genetic Association, was enrolled in the Society for the Promotion of

Agricultural Science, the American Society of Agronomy, the American Chemical Society, and an executive secretary of the Northeast Conference on Rural Progress. He was also a member of the Alpha Zeta, Phi Gamma Delta, and Phi Kappa Phi fraternities, of the Shakespeare and Cosmos Clubs of Washington, and of the Episcopal Church of Chevy Chase.

H. R. SMALLEY

BOOK REVIEW

FORAGE PLANTS AND THEIR CULTURE

By Charles V. Piper, Agrostologist, Bureau Plant Industry, United States Department of Agriculture. The Macmillan Company, New York. 671 pages, 74 figures, 14 plates. 1924.

In revising this book, the author has incorporated the more important new knowledge contributed in the past nine years to the subject of forage crops. He points out with much truth and emphasis the economic importance of forage crops and the fact that the present status of knowledge concerning farm forages is not nearly so complete nor so accurate as it is concerning such crops as the cereals, cotton and tobacco. The weakest place in the knowledge of forage production in American agriculture is unquestionably that relating to pasture and pasturage. This is true notwithstanding the fact that pasturage alone furnishes equally as much feed as all the harvested forages.

This revised edition is undoubtedly the foremost work on forage crops available at this time. It is amply illustrated. The statistical information is very forcibly presented, with maps and tabular data based on the 1920 census reports. A very complete index adds the usual value to the text and among the other features carefully selected list of references at the end of each chapter gives this work an outstanding value for use in the classroom. L. F. Graber.

AGRONOMIC AFFAIRS

MEETING OF THE CORN BELT SECTION OF THE AMERICAN SOCIETY OF AGRONOMY

The summer meeting of the Corn Belt Section of the Society was held at the Iowa State College on August 28 and 29, to inspect the investigational work in Farm Crops and Soils.

Many of the visiting agronomists reached Ames on Wednesday and on the evening preceding the meeting all gathered at the Acacia fraternity house where a most enjoyable get-acquainted session was spent.

On Thursday morning at 9:00 A. M. the opening session was held in Agricultural Assembly, with past-president Dr. C. R. Ball presiding. Acting-president Herman Knapp of the Iowa State College welcomed the visiting agronomists and response was made by Dr. Ball in behalf of the Society. President M. F. Miller of the Society reached Ames during the opening meeting. Dr. W. H. Stevenson described briefly the organization and work of the Farm Crops and Soils Section of the Iowa Agricultural Experiment Station, after which there was a tour of inspection of the laboratories, class rooms and offices. Immediately following this tour, the visitors broke up into groups for conferences with members of the staff and to go over special phases of the work more in detail. The crops specialists met on the campus near the campanile while the soils men visited the laboratories.

The following members of the staff discussed their work:

Farm Crops

"Cooperative Crop Experiments," Prof. J. L. Robinson.
"Forage Crop Investigations," Prof. F. S. Wilkins.
"Instructional Work in Crops," Prof. J. B. Wentz.
"Small Grain Investigations," Prof. L. C. Burnett.
"Corn Investigations," Prof. M. T. Jenkins.
"The Seed Laboratory," Prof. H. D. Hughes.

Soils

"Humus Investigations," Dr. H. J. Harper.
"Agronomy Farm," Prof. L. W. Forman.
"Instructional Work," Dr. W. H. Stevenson.
"Soil Bacteriology," Dr. P. E. Brown and Dr. L. W. Erdman.
"Soil Survey and Field Experiments," Dr. W. H. Stevenson and Dr. P. E. Brown.
"Soil Fertility Investigations," Dr. Paul Emerson.

After luncheon at the Maples, President Miller called on representatives to introduce all those present from their states and the following nunbers were found to be present from the several states. Nebraska, 7; Minnesota, 8; Illinois, 12; Kansas, 9; Wisconsin, 5; Indiana, 5; Michigan, 3; Missouri, 4; South Dakota, 5; Texas, 1; Louisiana, 1; Oregon, 1; West Virginia, 1; Utah, 1; New York, 1; Canada, 4; Washington D. C., 4; and Iowa, (about) 30.

At 1:30 P. M., an auto trip was taken to the College Field where the crops experiments were inspected and explained by Professor H. D. Hughes, F. S. Wilkins and others on the crops staff. At 4:30, there

was an auto tour of the campus and college farms, after which the members enjoyed a swim in the pool at the gymnasium.

Dinner at 6:00 P. M. at the Maples was followed by a sesssion at Agricultural Assembly, where two moving pictures were shown, "The Corn Belt Derby" and "Pay Dirt," the latter having been written, staged and produced at the Iowa State College. Some lantern slides were then shown and briefly discussed by Professor H. D. Hughes and Dr. W. H. Stevenson, setting forth some phases of the work in farm crops and soils which could not be shown in August.

A brief business meeting was held, at which it was voted that the next summer meeting should be held at the Michigan Agricultural College at East Lansing, Mich. with Professor J. F. Cox in charge.

On Friday, the visitors were taken by auto to the Agronomy Farm and at 9:00 A. M., after an explanation of the history and layout of the farm and of the experiments by Dr. W. H. Stevenson, the soil experimental plots were visited and inspected many stops being made to discuss questions arising in regard to the different tests.

Luncheon at the College Inn Cafeteria was followed by a return to the Agronomy Farm and inspection of the crops experiments. A dinner was held jointly with the National Soy Bean Association at 6:30 at the Maples after which the members attended the opening session of that association.

P. E. BROWN, *Secretary*

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AGRONOMIC SCIENCE AND INCREASED PRODUCTION[1]

M. F. Miller[2]

It is a commonplace statement that the United States has reached a point where the fertile and readily usable agricultural lands have all been put under cultivation. Future increases in production therefore must come through the use of marginal lands, the reclamation of some potential lands requiring drainage or irrigation, and the increase of acre yields. As agronomists, it might be worth while for us to consider the third of these possibilities, that of increasing the acre output. I realize that to enter such a field of speculation may seem unprofitable. In fact, there are so many unknown factors which may become operative in the future that it may seem folly to consider the subject at all. Nevertheless, speculation is interesting and by means of it we may at least set goals toward which to work. It may not be amiss, therefore, to consider the probable need and the desirability of increased yields, the limiting factors, the probable future trend in acre yields and the agronomist's relation to the matter.

The need of increased production is, of course, not apparent in our present economic life. As a matter of fact, we have heard much regarding overproduction in the period following the war. Many persons have become obsessed with the idea that the problems of distribution and marketing are all important. Some even fear that the efforts of agronomists may result in disastrous overproduction. It must always be remembered, however, that only a comparatively small number of farmers have as yet made any serious attempt to follow our teachings and that most farmers change their methods very slowly. The question, then, is whether the future need for food stuffs

[1]Presidential address read at the annual meeting of the American Society of Agronomy, at Washington, D. C., November 10, 1924.
[2]Professor of Soils, University of Missouri, Columbia, Mo.

may not become keenly felt, in spite of our best efforts. Naturally, this will depend primarily upon the rate of population increase, along with such influences as the increase of imports and the market prices of farm products.

It may seem idle to speculate on the increase in population of continental United States. If the curve of increase rises at anything like the rate which has been common to the last half century, we shall have hosts of people to feed in a few more generations. There are, of course, those who take great pride in our increasing numbers, and doubtless within certain limits such a pride is justified, but unlimited increase is certainly not desirable.

Doubtless many of you have read Dr. East's interesting but depressing book, "Mankind at the Crossroads," in which he insists that the Malthusian law still applies and that our future population will be limited only by the amount of food available for sustenance. Dr. East fears that within the next fifty years, should our present rate of increase continue, we shall have passed beyond the possibility of maintaining anything like our present standards of living, and that when this condition is reached it will be impossible to lift ourselves up again. He holds that the next half century will show whether we are to curb our increase in numbers, so as to maintain a satisfactory living standard or whether we are to reach a point of population saturation based on a living standard such as is common to some of the more densely populated countries.

It seems to me that for a people accustomed to the average standard of living in this country, the possibility of an excessively large population is unlikely. It must be remembered that our people have always been accustomed to a high living standard and there is every reason to believe that we shall make every effort to maintain it at a comparatively high level. There are already signs of a change in our rate of increase. We are restricting immigration and there are indications of a marked restriction of the birthrate among native born Americans. As a matter of fact, the increase of population between 1890 and 1900 was 13,046, 861; between 1900 and 1910 it was 15,977,-691, while between 1910 and 1920 it dropped to 13,738,354.

Doubtless many of you are familiar with the work of Pearl and Reed, in which, by the application of a formula based on biological principles, they have estimated our maximum population at approximately 200 millions. These calculations indicate further that this number will be reached at about the year 2000. It would seem that such a figure is a fairly reasonable one. We may, of course, go higher by means of improved methods of food production and because slight

changes in the diet are possible without interfering materially with our general well being. It is probable, however, that the year 1950 will see approximately 150 millions of people in this country and the year 2000 not less than 200 millions. Hence, the problem arises of supplying such a population with sufficient food and clothing to maintain a reasonably high standard of living. Moreover, it is probable that food and clothing cannot be considered alone. There is a strong probability that before the matter of the food supply becomes acute, if it ever does, our farmers will be supplying materials from which alcohol or other fuels may be manufactured.

In the light of our probable future population, it seems perfectly evident that production must be increased. However, the situation is somewhat complicated by the matter of future imports and exports. Here one again enters the field of speculation. With respect to exports, there is little doubt that the exportation of food stuffs will be eliminated as the demand increases at home. While the amount of our exports has varied rather widely, we are now exporting grains, cotton and animal products requiring for their production about 17% of the cropped land acreage. We shall doubtless continue to export cotton, in quantity, for a long time to come, since our conditions are peculiarly favorable for its production. We may develop also an export trade on other less important crops, but a curtailment of the export of our principal food products is in sight.

In the case of imports, it is difficult to see very far into the future. While it is certainly safe to plan to be a self-sustaining nation, yet so long as there are regions of the world where the food resources exceed the demands of the population, so long as we have an open sea, and so long as we have manufactured products to ship abroad, we shall doubtless import considerable amounts of food materials. The increase in world population from 780 millions in 1820 to 1700 millions in 1920 has been due largely to the development of ocean transportation and to the free movement of food materials. This is shown by the fact that the principal increases in population have been in those countries in which industry and transportation have been most highly developed, and not in those countries of retarded industrial development, such as China and India. The industrialized nations have been buying a considerable share of their food stuffs from nations with greater soil resources. England is the most striking example, as she imports approximately four-fifths of her food supply. Before the war, Germany was importing one-fifth, and Italy about one-third, of the needed food stuffs.

But even those nations which are producing an exportable surplus

are importing certain foods. In our own case, we are importing large amounts of rice, sugar, cocoa, bananas, olive oil, coffee and tea. While some of these are in the nature of luxuries, others are substantial foods. There is little doubt, too, that in the immediate future, unless the tariff intervenes, we may expect considerable importations of wheat. Canada, South America and Australia have large quantities for export. In time, Russia will probably again be an important exporting country. There is good reason to believe, therefore, that for some time to come the world price of wheat may be so low as to make competition under our conditions rather difficult.

The matter of possible imports is complicated also by the trend of world settlement and the white man's conquest of the tropics. If Huntington's views prove correct, the great civilizations will be limited to those regions which experience rather marked temperature changes and violent cyclonic storms, such as those of Western Europe, Japan and the United States. More recently, the independent investigations of Taylor have led to quite similar conclusions. However, Taylor includes the coal supply and potential agricultural production, as well as climate, among the determining factors. He concludes that future white settlement will center around London, England, Sidney, Australia, and Chicago in this country, with less important centers around Buenos Aires, South America, and Durban, South Africa. Such considerations are important in determining how far the white race may go in controlling the world's food output. It seems very likely that the whites will be segregated in regions most favorably located with reference to climate, a supply of food stuffs, and the possibilities of industrial development. Yet, they may be able to control production in regions unfavorable to white settlement. Through the plantation system and the use of native laborers, whites are already controlling no small amount of the production in the tropics. It is possible that such a system may be greatly extended, through the development of air communications and the improvement in the facilities for ocean transportation, particularly in the matter of fast freight boats and refrigeration.

But, in spite of the possibilities of imports, it is doubtless only a question of a century or less until, with the increase not only of our own but of world population, the percent of food stuffs imported will be comparatively small. It is certainly reasonable, therefore, to look forward to the time when our total production may be greatly increased.

We are indebted to the Federal Committee on Land Classification, appointed by the Secretary of Agriculture in 1921, for an

exhaustive analysis of the matter of probable future land utilization. This committee has assumed a population of 150 millions by 1950, and, by a very exhaustive consideration of the conditions, it has shown that if no change in the acre-yield, or in the rate of consumption, should take place, we should be required to utilize for crops, pasture and forest, approximately 900 millions more acres than are included in our entire territory, including deserts and waste. Therefore, we have two options first, that of increasing our acre production of crops, pasture and forests, and second, that of greatly changing our per capita consumption. Of course, what we shall do is to make use to a certain degree of both these options. But, as the committee points out, there is also the possibility of increasing the cropped acreage by the utilization of some of our marginal lands, and by the reclamation of some of the irrigable and swamp lands. It is assumed, however, that in the case of such utilization, it will proceed only in so far as crops may thus be produced more economically than through increasing the yields of existing cropped land. It is assumed also that the per capita consumption, particularly of beef, will be lessened somewhat, along with a decreased per capita use of timber products. If allowance is then made for an elimination of our exports, excepting cotton, the committee believes that 150 millions of people can be supported with a comparatively small increase in the yields of the cropped land. But without doubt 150 millions is much short of our maximum population. It is probable that many of our children will live to see a population of 200 millions within our borders. We, of course, have large areas of land of moderate to low fertility which may yet be utilized, but we must remember that China with 300 million acres of land more than we have, is supporting but 300 millions of people. What she is doing we shall probably do, cultivate more intensively our better lands, expanding into poorer lands only as conditions warrant. Moreover, we shall probably always remain a meat-eating nation, to a far larger extent than many of the older countries, utilizing much of our poorer lands for pasture. It seems perfectly evident, therefore, that we are certain to increase our production and the acre yields of our cropped lands as time goes on.

In the light of our present agronomic information, the possibilities of an economic increase in the acre production of individual farms or by individual farmers are considerable. This is shown by experimental data and by the experiences of farmers. For instance, the Ohio experiment station, on tracts of land 10 acres in size (which takes them out of the plot class) has been able, by proper soil treatment, to maintain a fifteen year average yield of 78 bushels of corn,

60 bushels of oats, 35 bushels of wheat and 3 tons of hay. At the same time, the 10-year average yield of the farmers of Ohio has been only 37 bushels of corn, 34½ bushels of oats, 16½ bushels of wheat and 1.1 tons of hay. Many similar experimental data might be given. The experiences of our best farmers in maintaining high average yields show somewhat similar possibilities. Exceptional men secure yields practically as high as these, while the average yields in their counties or states may be less than half as much.

It is of course the matter of raising the average yield rather than the individual yield that is the important consideration. Average yields can be increased but slowly. Nevertheless, the Committee on Land Utilization has shown that the average yield of the principal grain crops was about 16% greater in 1918-22 than in 1883-87, while the potato yield was 28% greater and the hay yield 25% greater. This is certainly not a bad showing, although it is interesting to note that the increase in the yields of all these crops has been much smaller during the last half of this period. The committee suggests that the increases here recorded were due primarily to better cultural methods resulting from the use of improved machinery and to an increase in the use of commercial fertilizers. But the slowing down of the rate of increase is very significant. Undoubtedly, we are reaching a point when further increases must be secured through greater effort and through a wider application of the principles of agronomic science. If, by the application of proper methods, individual farmers can increase their yields 50 percent, what opportunity has the average farmer of doing this? There are, of course, many reasons why such an increase can be reached only with great difficulty. As agronomists, interested both in an increase in yields and in the improvement of the quality of farm products, it might be well for us to consider some of the more important of these reasons. Such a consideration should enable us to realize the importance of our task and lend zest to our future efforts.

One of the first of the limiting factors, which might be mentioned, is that of the increased cost of production with increasing yields. It is true that, for a given individual, a substitution of proper for improper methods may mean less cost per unit of product, but when an increase in the average yield of a county or state is considered, additional units usually mean added cost per unit and certainly added cost per acre. This increase lies first in the cost of labor. It has been the history of agriculture that increased yields have been accompanied by an increase in human effort, resulting in practically every instance in lowering the standard of living. It is possible that in our case this may be in part or wholly offset by further improvements of agricul-

tural machinery. It is doubtful, however, if we shall be able, even with our most improved farm implements, to hold down appreciably the labor cost either of man or of animals.

Another factor contributing to increased cost is that of maintaining soil productivity, either through the maintenance of the natural stores of plant nutrients or through the addition of fertilizing materials. The time has passed, in the case of all but the newer soils of the western corn belt and some of the alluvial lands, when this matter can be disregarded. Even in the better corn belt states, we can no longer depend solely upon the stored fertility of our soils, neglecting entirely to include the cost of this item in our expense account. Productivity must be preserved, and in most cases increased, if the yield averages are to be advanced. In the corn belt states as a whole, this will mean more lime, more legumes, and more fertilizers. In the older states of the East and South, it will mean additional outlays for fertilizers over and above a large present usage. There is every evidence, therefore, that the use of commercial fertilizers in one form or another will continue to increase, over practically all of our cropped land. When the outlay per acre is considered, this can mean nothing but an increased cost of production.

Still another important factor, which is now contributing to the cost of production and which is doubtless to become of greater importance with time, is that of controlling insect pests and crop diseases. The effect of the boll weevil on the cotton crop is a good, but of course an extreme, example of what insects may do. The average yield of cotton has been greatly decreased by this insect, and, if its ravages are to be controlled, great efforts must be put forth. The European corn borer is another example. No one knows what it may do. Its insidious westward advance is certainly disconcerting. When we consider the great numbers of other insects, all of which require either direct expense in their control, or the substitution of crops or practices of less value, the cost of increased yields because of insect enemies can be understood, even if not actually measured. In the control of plant diseases, we have made but a beginning. Moreover, we shall have to contend not merely with those diseases that are now prevalent, but with those which are constantly being introduced. There is no doubt that one of the great items of cost in a further increase of yields lies in the control of these diseases.

These are some of the more important reasons why increases in the average acre yield must be secured at increased cost. When we consider further that many farmers will not have the ready capital to make the expenditures necessary for such increases, the difficulties

are still more apparent. It would seem, therefore, that marked increases in the average acre yield will require higher prices for farm products or a lower standard of living for the farmer. It is very probable that, to a certain extent, both conditions may obtain, although great changes in either direction are unlikely.

A second limiting factor, which applies particularly to our great food-producing states of the corn belt, is the preference of the farmer for extensive methods. Much has been said about the importance of "a little farm well tilled," but this has had little effect on the farmers of these great agricultural states, and those to the west. In the first place, land speculation has always existed in these states. The farmer has preferred to put his accumulations into more land than into those things which make intensification possible. He has, therefore, prided himself on his wide acres and his extensive methods. He has been interested much more in the output per man than in the output per acre. In the second place, the climatic conditions do not favor great intensification. These states are subject to a typical continental climate. It is certainly unfortunate that the great body of our food-producing land is so far inland that agriculture is greatly influenced by an unequal distribution, and in some instances by a marked deficiency, of rainfall. It must be remembered that the high average yields of western Europe are, in no small degree, due to a good distribution of the precipitation and an equable climate. We have a somewhat similar condition in the Eastern states, where an intensive agriculture, limited largely to the better lands and dependent on heavy applications of fertilizers, has resulted in average yields much higher than those common to the best lands of the corn belt states. As compared with the agriculture of the East, therefore, it seems doubtful if that of the fertile corn belt states, with their frequent summer droughts, can ever be other than semi-intensive.

In the third place, it must be remembered that the cost of fertilizer is higher in the corn belt states than it is in the East and South; while, on the whole, the unit value of the crops grown is lower. Such a condition influences adversely the use of large amounts of fertilizing materials. Moreover, there is little chance for a change in this condition until the center of population shifts further westward, so that these foods will be produced nearer the point of maximum consumption. All of these conditions which hold back the adoption of more intensive methods, militate against a rapid rise in the average acre yield in our principal food producing states.

A third important factor, limiting the increase in crop yields, is that of land tenure. This applies particularly to the better lands of the

corn belt states and to the South. In the corn belt states, land speculation has not only tended toward the development of extensive systems but it has resulted in much absentee landlordism and a wide adoption of the short-time lease. So long as marked land speculation exists in these states, we cannot expect improvement in this regard. Land owners are not willing to bind their lands in long-time leases, when there is a possibility that they may sell at a good profit within a year. We all know the disadvantages of the short lease system, with its accompanying soil deterioration and the consequent reduction in acre yields. In the cotton belt, where the tenant system has long existed there is the negro share-cropper and an economic condition which interferes greatly with maximum production. Both in the corn belt and in the cotton belt, therefore, the systems of land tenure tend to hold down acre yields. Moreover, there is no immediate relief in sight. Time and economic change are both required to remedy the difficulties.

The final limiting factor which I wish to mention is the lethargy and the lack of information among the farmers. I mention lethargy because we all know that the majority of farmers are slow to use the information they actually have. Doubtless the great difficulty, however, is that farmers haven't the information which would make possible a higher acre production; or if they have it, they lack the ability of organizing their work in order to put this knowledge into practice. After all, we may expect too much of them. It is quite likely that many of us, if placed in their position, would do little better. Farming is a very complicated business and the man who can produce large yields economically is the exception. A great deal depends upon the native business ability of the individual.

That yields will gradually increase there can be little doubt, but it seems evident that this increase will come slowly. It would be visionary to expect to attain, within any reasonable time, the yields common to the better European countries, which for the staple crops stand between 40% and 50% above our own. The Committee on Land Utilization sets a figure of 10% as the maximum increase to be expected within the next three or four decades. This, with a slight expansion of the cropped area, some minor modifications in the character of our consumption, and the elimination of imports, excepting cotton, will probably take care of the 150 millions of people expected by the middle of the century. But to provide for 200 millions, which will probably represent our numbers by the end of the century, will require an additional yield increase and some further expansion of our tillable area.

Some time ago, I made some calculations based on O. E. Baker's figures of the potential lands in the United States, and arrived at the conclusion that, after allowing for the lower efficiency of our marginal lands, it would require an increased yield of about one-third on our present area of improved land of 500 million acres to provide for 200 millions of people. It is very doubtful if such an increase can be expected, particularly in the light of the probable modification of the character of our consumption. Probably the maximum that we can expect within the century will be an increase of 25% of our present yields. This will, of course cover a somewhat larger acreage of improved land than at present, possibly one-fifth more, which would make the total production about the same as one-third increase of our present area.

To some persons an increase of 25% of our present yields may seem very easy of attainment; to others it may seem impossible, unless a very marked change in our standard of living should take place. Personally, I think such an increase is possible, by the close of the present century, but by no means easy to attain. In considering this matter, it would be well to remember that in comparison with the countries of Europe and the Orient this country is still very young. As a consequence, we have the opportunity of influencing, to a very considerable degree, the practices of our farmers, and while economic considerations are always paramount in controlling changes in production, either industrial or agricultural, we should be able to direct, in considerable measure, the future trend of farm practice. We should remember, too, that this country has been unique among the nations of the world in the efforts it has put forth to assist the farmer. In fact, the beginnings were made with the passage of the Morrill Act, at a time when great areas of rich, virgin prairie remained unoccupied. This act has been followed by the Hatch, Adams, Smith-Lever, and Smith-Hughes Acts, each providing for some special field of agricultural research, teaching, or extension. In addition, we have seen the development of numerous farmers' organizations, many of which have proved abortive; yet these efforts show that the farmer is attempting more and more to help himself. If we then consider the Federal Farm Loan Acts, which are destined to be of great aid to the farmer, not only in buying land but in financing better systems of soil and crop management, we certainly have reason to be hopeful for the future. Moreover, the agronomist should have a great part to play in this development. If the farmers were left entirely to their own devices in improving methods, the sons gradually building upon the methods of the fathers (as has been the case in the older countries),

there is little doubt that great sacrifices would ultimately be required in the standard of living.

It is the opportunity as well as the duty of the agronomists of the country to assist the farmer in meeting his difficulties. Fundamental research is needed on a great variety of problems. Every state has a different set of conditions to meet. Our extension men are constantly demanding more facts. Even the better farmers are often in advance of us, and are asking for information which we do not have. They realize their need of help. While I think we all have the utmost respect for the practical judgment of the American farmer, one cannot but be impressed with the many problems which are beyond his powers of solution. The opportunities and duties of the extension agronomist are, therefore, as great as those of the experimentalist. He will be called upon to play a heroic part in the dissemination of information. Just what form such extension activities may take, as time goes on, cannot be forseen, but it is certain that, if any consistent increase in production is attained, the farmers must practically all be reached and their practices materially modified. While a great deal can be done in dealing with the mature farmers, there is little doubt that it is in the training of the younger generations as they come on that the greatest progress will be made. Consequently, the stimulation of interest in agriculture in the schools, and particularly the development of special vocational schools, such as those organized under the Smith-Hughes Act, will have a profound effect upon the attitude, and ultimately upon the methods, of the farmers of the future. For these schools, as well as for the farmers themselves, the agronomists will be called upon to furnish trustworthy information. We should therefore expect that the demands upon us will become more exacting as the years go by.

THE EFFECT OF ROTATION AND TILLAGE ON FOOT-ROT OF WHEAT IN KANSAS, 1920-1924[1]

M. C. SEWELL and L. E. MELCHERS[2]

INTRODUCTION

Tillage projects at the agronomy farm of the Kansas agricultural experiment station indirectly have thrown some light on how to combat foot rot of wheat. This disease[3] was first reported in Kansas in 1920. During the past three years, it has caused considerable damage to wheat in the eastern part of the wheat belt of the state.

Foot rot was first noted in the field plots at the Kansas agricultural experiment station in 1921. The disease manifests itself by two more or less distinct symptoms. In the plots at the agronomy farm, badly stunted plants have occurred in well defined areas throughout the fields. In these spots, the plants produced only a few weak culms which turned brown and dry before the heads swelled in the boot. Figure 1 illustrates this symptom and Figure 2 shows a bundle of normal wheat in contrast. The second symptom is the presence of "white head" spots several weeks before harvest. The plants in these spots produce normal sized culms, but the heads turn white and contain, if any, only shriveled grain. A review of the literature on this disease has been made by Stevens (2).[4]

FOOT ROT OF WHEAT IN RELATION TO ROTATION

The appearance of foot rot in the tillage and fertility project plots, in which wheat has been grown both continuously and in rotation, has afforded an excellent opportunity to study the effect both of cropping systems and tillage methods on the disease.

The wheat seed-bed project at the agronomy farm (1) consists of two sections; an area of 15 plots which is cropped continuously to wheat, and an area in which the wheat is grown in rotation with corn and oats. The part of this experiment involving the continuously cropped wheat plots had to be abandoned in 1923 because foot rot decreased the yields to such an extent that they were no longer criteria of the effect of tillage on yield. Wheat in the rotation division of this project did not show the presence of foot rot, although it ad-

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[4]Reference by number is to "Literature Cited," p. 771.

joins the continuous wheat portion and the same implements were used in cultivating both fields.

The fertility project is located at a considerable distance from the tillage project. Included in the fertility project there is a series of 12 plots devoted to continuous wheat culture. Foot rot was present in 1922 and 1923 on nearly all of these plots, regardless of their fertilizer treatment. Where wheat was grown in two different rotations in this project there was not a sign of foot rot. The rotations were: alfalfa (four years), corn (one year), wheat (two years), in a 16-year rotation; and a three-year rotation of corn, cowpeas for hay, and wheat.

During the four consecutive years that foot rot has been in evidence at the agronomy farm, it is an outstanding observation that wheat in rotation has never shown any infection by foot rot.

RELATION OF TILLAGE TO FOOT ROT OF WHEAT

The continuously-cropped portion of the wheat seed-bed project contains fifteen one-tenth acre plots with eleven different tillage treatments. The tillage project, consisting of fifty-seven plots in which nineteen triplicate tillage treatments are included, is an outgrowth of the older wheat seed-bed project. The wheat seed-bed treatments and notations as to the prevalence of foot rot are given in Table 1.

TABLE 1.—*Tillage treatment of wheat plots, continuously cropped from 1910 to 1923, and its relation to the development of foot rot.*

Plot no.	Time and method of treatment	First appearance of foot rot	Prevalence of foot rot in 1923
1	Not plowed; disked at seeding	none	none
2	Plowed Sept. 15; three inches	1923	very slight
3	Double disked July 15; plowed Sept. 15; seven inches	1922	" "
4	Double disked July 15; plowed Aug. 15; seven inches	1922	slight
5	Plowed Sept. 15; three inches	1923	very slight
6	Listed July 15; ridges worked down	1922	slight
7	Listed July 15; ridges split Aug. 15	1922	very severe
8	Plowed Sept. 15; three inches	none	none
9	Plowed July 15; seven inches	1921	very severe
10	Plowed Aug. 15; seven inches	1921	" "
11	Plowed Sept. 15; three inches	none	none
12	Plowed Aug. 15; seven inches, not worked until middle of Sept.	1921	very severe
13	Plowed Sept. 15; seven inches	1923	very slight
14	Plowed Sept. 15; three inches	none	none
15	Plowed July 15; three inches	none	none

The plots listed in Table 1 were always seeded to the same strain of Turkey wheat drilled crosswise of the series. The plots were separated by six foot alleys. For the ten year period from 1910 until foot rot appeared in 1921, the treatments giving the highest yields were

seven-inch plowing in July and in August. These same treatments showed greatest infestation of foot rot. The disease was slight, or absent, on all plots plowed late, shallow, or merely disked. Figure 3 is a graphic comparison of the amount of foot rot damage in the various tillage treatments. The boundary lines of the very small infested spots present in plots 2, 3, 4, 5, and 13 in 1923 are indicated by double lines. There was no perceptible damage from foot rot on these plots, but there were present wheat plants that were not entirely normal.

Throughout the series of fifteen plots indicated in Figure 3, those which were plowed late, disked, or disked in July and plowed in September, did not show foot rot damage. In addition to this outstanding fact, plot 15, plowed shallow in July, did not show evidence of the disease. That tillage plays an important role in the spread or check of foot rot as it occurs in Kansas is indicated by a comparison of plots 8, 9, 10, and 11 in Figure 3. Plots 9 and 10, plowed respectively in July and August, were severely damaged by the disease, yet plots 8 and 11, which were plowed shallow in September and only separated from the former by six foot alleys, showed no indication of the disease.

A possible explanation for the foot rot infestation on the plots which were plowed early in the summer is that early deep working of the soil covers the infected stubble deep enough to prevent its drying out. The moisture and temperature relationships of the soil probably are important factors in aiding the organisms to retain or lose their vitality.

Additional evidence of the relationship of tillage to the development of foot rot was indicated in the continuously-cropped wheat series of the fertility project. Spots of foot rot were charted on this series in 1922 and in 1923. In 1923, cowpeas were planted after harvest, as a green manure crop. For this reason all plots were plowed late and shallow in the fall preparation for the seeding of wheat. In 1924, no distinct spots of foot rot could be seen on this series. The plan of the experiment calls for cowpeas as green manure every third year. The intervening years the plots are plowed early in the summer in preparation for wheat.

The extent of the damage by foot rot under certain tillage treatments can be emphasized by citing some of the data on yields. The average yields for the July- and August-plowed treatments, during the ten years prior to 1921, was 19.9 bushels per acre and for the September-plowed, 12.2 bushels. In 1923, three years after the appearance of foot rot, the July- and August-plowed treatments averaged 9.5 bushels per acre, a decline of 10.4 bushels. The September plowing gave an average yield of 8.5 bushels in 1923. This is a decline

FIG. 1. Stunted plants in a typical foot rot spot.

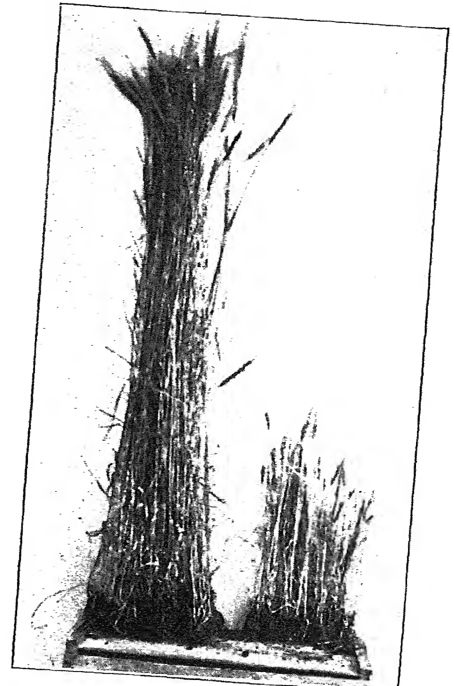

FIG. 2. Comparative height of normal and diseased plants.

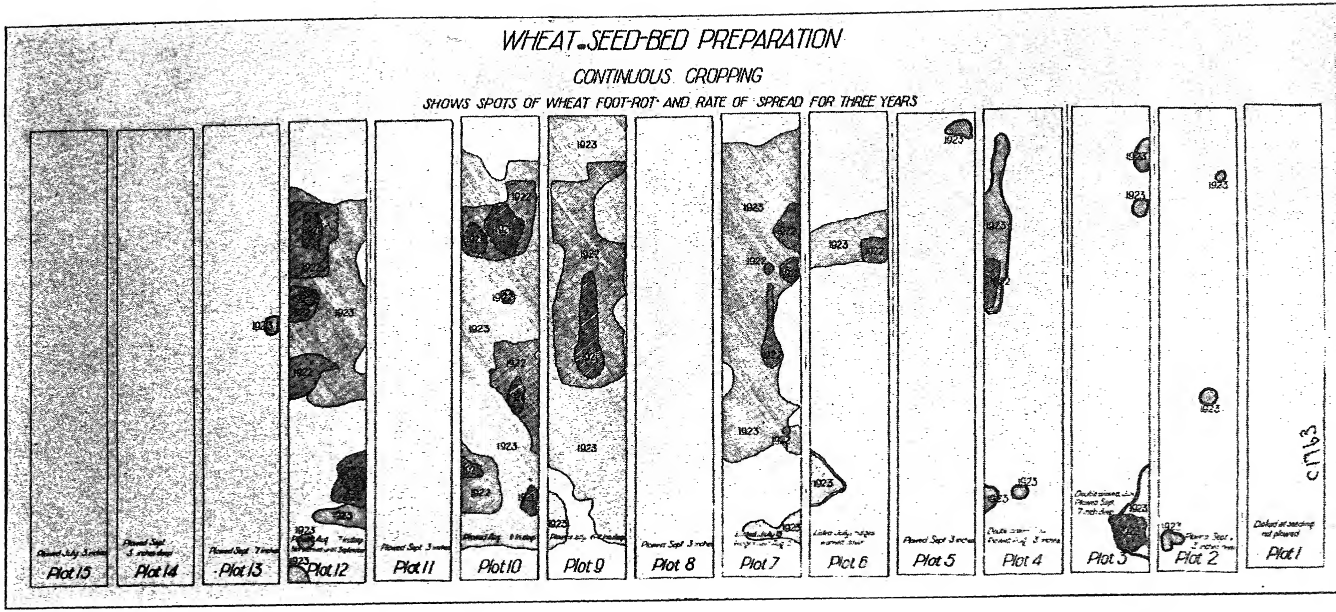

FIG. 3. Diagram showing spread of wheat foot rot in tillage plots continuously cropped to wheat on the agronomy farm of the Kansas agricultural experiment station in 1921, 1922 and 1922.

of 3.7 bushels below the normal yield for the treatment, a decline that must be attributed to the seasonal conditions because there was no evidence of foot rot damage. That the conditions for high yields were favorable under methods of early summer cultivation is shown by the fact that the plot disked in July and plowed in September made a yield of 28.4 bushels per acre. This plot did not show any foot rot damage, but there was some slight indication of infestation. Prior to 1923, this treatment had only averaged 17.4 bushels per acre compared with 19.9 bushels for the July and August plowing.

Foot rot was not in evidence on the new tillage project until the spring of 1924. The heaviest infestation was on the plots plowed seven inches deep in July and in August, but there was also severe damage on the plots plowed shallow in July.

More conclusive evidence of the relation of rotation to foot rot can be anticipated in a few years. The wheat seed-bed project, cited in this discussion, was planted to soybeans in the spring of 1924. After cropping to oats, wheat will again be grown. Also, rotation has been introduced into the tillage project.

SUMMARY

Foot rot of wheat has been present during the period 1921–1924 in the tillage and rotation experiments of the Kansas agricultural experiment station.

Wheat grown in rotation has not been damaged by foot rot. September plowing, with or without previous disking, did not favor the development of this disease.

Foot rot of wheat may occur in fields cropped continuously to wheat where the best tillage method for wheat production is practiced.

The continuity of long time experiments based on continuous wheat culture may be interrupted by foot rot.

LITERATURE CITED

1. CALL, L. E. The effect of different methods of preparing a seed-bed for winter wheat upon yields, soil moisture, nitrates. *In* Jour. Am. Soc. Agr., 6:249–259. 1915.
2. STEVENS, F. L. Foot rot disease of wheat—historical and bibliographic. *In* Ill. Nat. Hist. Surv. Bul. 13:259–286. Art. 9. 1919.

THE USE OF STANDARD SOILS WITH THE POTASSIUM THIOCYANATE TEST FOR ESTIMATING LIME-REQUIREMENT OF SOILS[1]

A. F. GUSTAFSON[2]

During the past year, the writer has been using what may be termed "standard" or "known" soils in connection with the potassium thiocyanate test (3, 4)[3] for estimating the quantity of lime needed per acre by red clover and alfalfa, or sweet clover, to enable them to make good growth. These standard soils are soils whose lime-requirement has been estimated by several of the common methods and on which the field response of clover and alfalfa to liming is known.

By studying a large number of soils in the field, where the growth and condition of crop was noted and where information was secured as to when the soil was limed and the kind and quantity of lime applied to the acre, it was possible to work out a dependable correlation between the lime-requirement of red clover, or alfalfa, on a given soil and the color developed on testing representative samples of that soil with the "richorpoor"[4] or other potassium thiocyanate solution.

In attempting to determine the lime-requirement of clover, it is well to consider several factors. (a) The length of the rotation, is important; a larger application of lime will be needed for clover in a long rotation of seven or eight years than in a short one of three of four years. (b) The quantity of manure used per acre and where in the rotation it is applied with respect to clover, whether for corn one year preceding it, on the new clover seeding or for crops following it, should be considered. (c) The quantity of acid phosphate or other fertilizer used on the small grain crop in which the clover is seeded needs its share of attention. (d) The fineness of limestone, when this form is being used, must have due consideration. Limestone, or other liming material, corrects the soil condition which for the present

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[3]Reference by number is to "Literature Cited" page 776.

[4]"Richorpoor" is the trade name of a potassium thiocyanate test solution for soil acidity. It is a slight modification of the solution suggested by Comber. The test is made by placing a few grams of soil in a test tube and adding a few cubic centimeters of the solution. (The writer is using a test tube approximately five-eighths of an inch in diameter, because of greater convenience in putting in the soil and solution, and of the greater facility with which this size may be cleaned compared with tubes of smaller diameter.) The tube is shaken vigorously to bring the solution into intimate contact with the soil, after which it is allowed to settle. If a deep red color develops the soil is considered as having a relatively high lime-requirement. A pink color indicates a low lime-requirement and when the solution remains colorless the soil is neutral or alkaline.

purpose may be called "acidity," thru an intimate surface relationship with the colloidal matter and the finer particles of the soil. For this reason, it is desirable that limestone, or other material, be reasonably fine so as to present a large surface for possible interaction with the soil material. Limestone screenings, which contain all the material passing thru a screen with four meshes to the linear inch, will have a large proportion of material with but relatively little surface for contact with the soil particles, consequently a much larger application per acre of this coarse material than of finer grades must be made to secure the desired effect on clover or alfalfa.

For alfalfa it is desirable, if not in fact absolutely necessary, to test a representative sample of the subsoil, say the stratum from 18 to 24 inches or more below the surface, as well as a sample of the surface soil. This is because of the fact that one soil may have carbonates in the subsoil while another does not. It is obvious that the latter will require much larger applications of lime to secure a satisfactory growth of alfalfa. This difference in the subsoil will have much less effect on recommendations for red, and especially for alsike, clover, the latter being shallow rooted.

A number of other factors, such as the character of the soil, its texture and state of fertility, the possible presence of manganese compounds, and the proportion of active aluminum compounds, all require proper consideration. It is assumed, however, that when iron is soluble in the test solution aluminum is at the same time in an active or detrimental condition, and for all practical purposes this is probably the case.

With these conditions and factors in mind, the standard soils are chosen so that one has a high lime-requirement, another a medium, and a third a low lime-requirement. For demonstration meetings, a fourth soil which is neutral or alkaline and so has no lime-requirement may well be added. Unknown soils, such as samples sent to the college by farmers or county agents or which farmers may bring to soil testing demonstration meetings, may be compared directly with the "standard" soils. The "standard" soils are tested along with each soil or group of unknown soils. All soils in any one examination are treated as nearly alike as possible, using the same quantity of soil, and the same quantity of solution in each test tube, shaking for the same length of time, setting up to settle and develop color as nearly simultaneously as possible, and allowing all soils to settle for the same length of time. Also it is necessary that the soils be of approximately the same moisture content. A "sour" soil when wet gives a faint color or none at all; when moist it gives a deeper color; and when air

dry a still deeper shade of pink or red develops. It is the writer's experience that unreliable results are likely to be obtained if the soils are not practically air-dry when tested with the commercial "richorpoor" solution. Emerson (5) has proposed a method of obviating this difficulty with wet soils. Smith, Bauer, DeTurk and Smith (7), as well as Harper and Jacobson (6), have found it unsatisfactory to use the "richorpoor" test on wet soils. It is equally essential that soils be comparable as to physical composition, at least to the extent of eliminating coarse gravel.

The potassium thiocyanate method of estimating lime-requirement of soils, in common with several others, is qualitative in principle, but soil workers are attempting to secure quantitative results with it. For this reason (2), it is absolutely necessary that all precautions which may contribute to uniformity thruout the test be taken.

Color readings may be made soon after the larger soil particles have settled, or when the solution is reasonably clear; but it is preferable to make them after thirty or forty minutes of sedimentation, the time depending somewhat on clay content of the soil. However, readings may be made after several hours, or on the following morning, since all samples are being examined under practically identical conditions. By comparing the color developed by the unknowns directly with that of the standard soils one may estimate the quantity of limestone to the acre needed for clover with a reasonable degree of accuracy. It does not seem practicable to estimate more closely than one-fourth of a ton of finely ground limestone to the acre.

It has proved intensely interesting in demonstration meetings to add a small quantity of quick or hydrated lime to a test tube containing a soil deficient in lime with red colored solution above it. The red color quickly disappears. The lime according to the farmer's viewpoint "neutralizes soil acidity," and he is therefore deeply interested as he is assured that such a test has a practical bearing under his soil conditions.

During recent months a considerable number of sets of these "standard" soils have been furnished to county agents and Smith-Hughes high school agricultural teachers in New York State for use in the soil and crops work with their constituents.

WHY STANDARD SOILS RATHER THAN A COLOR CHART

In using this method of estimating lime-requirement for clover it was noted at the outset that the red coloration which characterizes soils deficient in bases becomes deeper on standing. The greatest intensification of color occurs during the first few hours, as might be

expected, but the change is appreciable up to thirty-six and even to forty-eight hours, or longer. Another factor affecting the color is the relationship between the quantity of soil and the quantity of potassium thiocyanate solution used in a "test." On testing a soil with a marked lime-requirement for clover a quantity of soil, say ten grams, is used with ten cubic centimeters of the test solution and a certain color develops. Suppose but one-half as much solution, five cubic centimeters, is used with this quantity of soil a much deeper color is obtained, while on the other hand, if twice as much, or twenty cubic centimeters, of the solution is used with the same amount of soil a much lighter color results. It is obvious that the soluble iron which is responsible for the red coloration is much less concentrated when twenty cubic centimeters are used than when five cubic centimeters of the solution are employed. Thus using varied quantities of solution with the same amount of soil gives markedly different shades of color for the same soil. For this reason it is imperative that a definite relationship between quantity of soil and of solution be maintained in testing a group of soils including the standard soils. It is not necessary that this same definite relationship be held for every test when standard soils are used. This would be absolutely essential, however, when a color chart is employed.

Differently made solutions of potassium thiocyanate give varied colors with the same soil. A solution made by saturating 95 percent ethyl alcohol with potassium thiocyanate gives a much deeper color on testing a "sour" soil than does the "richorpoor" solution, but the soil settles more slowly from the alcoholic solution. For this reason the same solution should be used thruout a test.

The use of standard soils has one very distinct advantage: the lime requirement of soils for clover can be estimated at any time after settling has occurred, during a period of twenty-four hours.

The writer has seen two color charts; one furnished by the Richorpoor Company of Urbana, Illinois, the other published by Bear (1). The latter is quite suggestive and is useful as a starting point. To be of the greatest service a color chart should be accompanied by a statement of definite quantity relationship between soil and test solution, and the length of time which should elapse between shaking soil and solution together and making the estimate of lime requirement. Furnishing this information has been attempted with Bear's chart just mentioned and, in part, also with the "richorpoor" chart.

Owing to all of these variable factors of which it is difficult to take account in a simple color chart, the use of standard soils is proposed. It must be borne in mind that there is a very large personal equation

in a test of this sort. The writer's experience does not indicate that this test is likely to be of much value in the hands of farmers or others not having some laboratory training. It will probably be necessary for each worker to develop standard soils for his own section. This will require some time and experience in the field, but it is possible to develop a useful correlation between the lime-requirement as estimated by this test and the response of clover and alfalfa to liming in the field.

LITERATURE CITED

1. BEAR, F. E. Soil Management, Wiley & Sons, N. Y. pp. 187–88. 1924.
2. CARR, R. H. Measuring soil toxicity and basicity. *In* Jour. Ind. Eng. Chem. 13:931–33. 1921.
3. COMBER, N. M. A qualitative test for sour soils. *In* Jour. Agr. Sci. 10:420–424. 1920.
4. COMBER, N. M. A modified test for sour soils. *In* Jour. Agr. Sci. 12:370–71. 1922.
5. EMERSON, PAUL. A suggested laboratory and field test for soil acidity. *In* Jour. Amer. Soc. Agron. 15:495–499. 1923.
6. HARPER, HORACE J., and JACOBSON, H. G. M. A comparison of several qualitative tests for soil acidity. *In* Soil Sci. 18:75–85. 1924.
7. SMITH, R. S., BAUER, F. C., DETURK, E. E., and SMITH, L. H. Ill. Agr. Exp. Sta. Soil Rept. 26. pp. 44. 1924.

A COMMON ERROR IN INTERPRETING FINANCIAL RETURNS FROM FERTILIZER EXPERIMENTS[1]

E. L. WORTHEN[2]

Many of the more recently established fertilizer experiments compare various grades of fertilizer on the basis of a single, but uniform, rate of application. There has been a tendency to apply equal amounts of fertilizer rather than equal quantities of nutrients. The idea has been to determine which of several grades of fertilizer will return the greatest profit under a given condition. It is obvious that in such comparisons the difference in the cost of the fertilizer will vary with the grade applied. In the interpretation of the results, the difference in the cost of the treatments is often taken into consideration and proper adjustment attempted in order to determine which treatment is the most profitable.

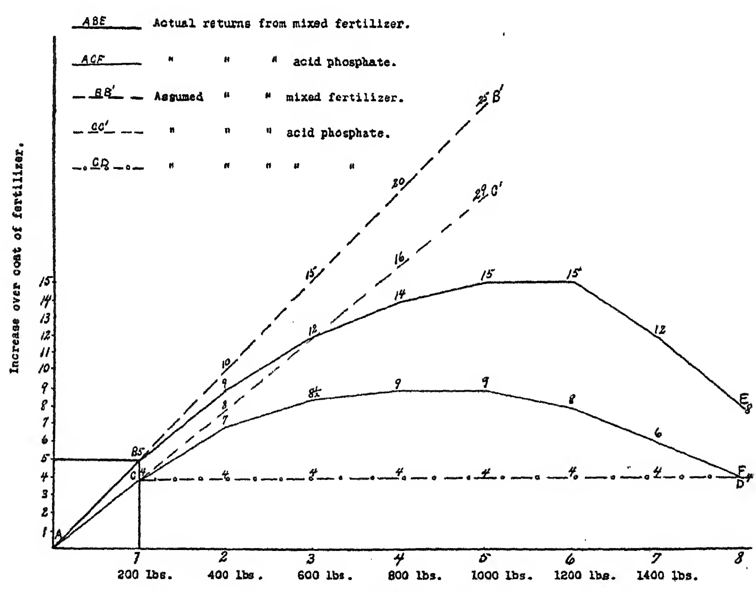
In connection with agronomy extension work in a number of states, field demonstrations or tests have been established to determine which of two or more fertilizers will return the greatest profit. Farm-

[1]Contribution from the Department of Agronomy, Cornell University, Ithaca, New York. Received for publication October 20, 1924.

[2]Extension Professor of Soil Technology.

ers often desire to know whether they should use acid phosphate or a mixed fertilizer. They are not infrequently advised "to try it out;" and, as a result, a demonstration is established, not with the idea of demonstrating the superiority of one treatment over the other, but rather of testing the two fertilizers in order to find out which is the more profitable. In such tests, the practice is to make the same rate of application of the acid phosphate as of the mixed fertilizer.

The writer contends that in all such comparisons, it is not possible to make accurate corrections for the difference in the cost of the treatments. There have been two methods followed in the past, both of which necessitate assumptions which cannot be justified. In the one method (not used extensively at present) the financial returns are calculated on the basis of the interest on the investment (1).[3] In the other, which simply consists of deducting the cost of the fertilizer from the value of increase, it is assumed that adequate adjustment has been made for the difference in the cost of the treatments, and the fertilizer giving the largest net return is considered the most profitable (2, 3).



In order to analyze the two procedures, and to see wherein they fail to make an adequate adjustment of cost differences, it is necessary to refer to the accompanying graph. In the preparation of this, it is

[3]Reference by number is to "Literature Cited," page 781.

assumed that acid phosphate is compared with a mixed fertilizer. The rate of application is 200 pounds and the unit of crop produced—say one bushel—is worth one dollar. Acid phosphate is assumed to cost $20.00 and mixed fertilizer $40.00 a ton. It is also assumed that the following results are secured:

	Bushels increase	Value of increase	Cost of fertilizer	Value of increase over cost of fertilizer
200 lbs. acid phosphate........	6	$6.	$2.	$4.
200 lbs. mixed fertilizer........	9	$9.	$4.	$5.

These increases are represented in the small square in the lower left hand corner of the graph. The heavy line A B is based on the net returns from mixed fertilizer and the lighter one A C on those from acid phosphate.

By applying each of the two methods available for making corrections in the difference in the cost of the two treatments, the following conclusions are reached. According to the first method, an investment of $2.00 in acid phosphate has, in addition to paying for itself, given 200 percent profit on the investment. The mixed fertilizer, on the other hand, has returned a profit of $5.00 over and above its cost, or only 125 percent on the investment of $4.00. Therefore, acid phosphate has returned a greater profit than the mixed fertilizer. Nevertheless, according to the second method, the mixed fertilizer has paid for itself and returned $5.00,while the acid phosphate gave only $4.00 over and above its cost. The additional $2.00 invested in the mixed fertilizer has been repaid and a dollar profit secured besides. Therefore, this additional investment of $2.00 in the mixed fertilizer is desirable because in addition to paying back the principle it has earned 50 percent on the investment. Consequently, the mixed fertilizer is more profitable and should be used in preference to acid phosphate alone.

What is really desired to be known is whether or not this $4.00 investment in mixed fertilizer returned more than the same investment would have done in acid phosphate. The writer believes that this information cannot be secured with single applications of the materials compared, unless the cost of the treatments is identical. In applying either method suggested for determining, under such conditions, the most profitable treatment, one makes one or the other of two assumptions, or what is more probable, fails to reason the situation to a logical and complete conclusion.

Where the computation is to be based on the interest returns on the investment, it must be assumed that each additional unit of fertilizer

would give an equal increase to that secured from the first unit application. The dotted lines B B′ and C C′ give, respectively, the assumed increases from additional applications of mixed fertilizer and of acid phosphate, on this basis. These lines, as can be plainly seen, give the old Liebig curve.[4]

The other method, which is now commonly used in interpreting financial returns from soil treatments, is represented by the line C D. In this case, the possibility of obtaining paying returns from additional acid phosphate is ignored and the impression is commonly given that additional units of acid phosphate will give no increase in net return above that produced by the rate of application used in the experiment. That is, additional units of acid phosphate will simply pay for themselves and a net return of $4.00 will be secured from acid phosphate irrespective of the rate of application. The line C D then, in the case under consideration, represents the inferred increase, or value of increase, from additional applications of acid phosphate.

In order to discover wherein these two types of curves differ from actual results, it is necessary to assume that additional units of acid phosphate have been applied and that the increases from the same are known. In order to chart a true curve for additional units of acid phosphate and mixed fertilizer, the following increases which are certainly within the realm of expectancy, have been assumed for additional treatments.

Amount of fertilizer pounds	Unit increase or value of increase from acid phosphate	mixed fertilizer
200	6	9
400	11	17
600	14½	24
800	17	30
1000	19	35
1200	20	39
1400	20	40
1600	20	40

These assumed increases are represented by curve B E for mixed fertilizer and C F for acid phosphate. Since expected increases would be proportionately less from additional units of material applied, these figures tend to be in accord with Mitzcherlich's law of the minimum,[5] and the curves B E and C F to approximate a curve based on this law.

[4]Liebig's curve is based on the assumption that each additional unit of fertilizer will give an increase equal to that produced by the first unit of application. That is, equal increases will be secured from each unit of application until the rate of application becomes so great that additional fertilizer is ineffective.

[5]Mitscherlick's law of the minimum holds that the increase in crops resulting from additional units of an element in the minimum bears a definite proportion to the decrement from the maximum. That is, a second unit of fertilizer will return less than the first; a third proportionately less than the second, and so on until finally the maximum return is secured.

In case of mixed fertilizers, curve B E is ascending for the first five units of application. Up to 1000 pounds to the acre, this mixed fertilizer returns a profit on each additional 200 pound unit applied. The sixth unit merely pays for itself; the seventh, while still giving a slight increase, is made at a financial loss; while the eighth produces no increase whatsoever. In the same way, curve C F represents increases for acid phosphate up to 1200 pounds to the acre, the first four units of application all give some profit, the fifth pays for itself, while the sixth was a financial loss. Acid phosphate in excess of 1200 pounds gives no increase.

The case in question, where 200 pounds of acid phosphate costing $2.00 is compared with 200 pounds of mixed fertilizer costing $4.00, can now readily be analyzed. The second rate of application of acid phosphate gave an increase of $7.00 over its cost as indicated by curve A F. The assumed increase, when calculations are made on the basis of percentage returns on the investment, is $8.00, as indicated by Liebig's curve. When comparisons are made on the basis of net gain secured by subtracting the cost of fertilizer from the value of the increase, the net increase is still considered as $4.00, since the possibility of obtaining increases from additional acid phosphate is ignored. This is indicated by the line C D. Since the returns secured from an assumed application of 400 pounds of acid phosphate as determined by interest on the investment, are greater than those actually secured, it is evident that this method is favorable to acid phosphate, which is the cheaper of the two fertilizers. In the same way, the method which compares net returns from fertilizer applied favors the more expensive mixed fertilizer, since it assumes a net return of $4.00 from a 400 pound application of acid phosphate, when in reality it produced $7.00 over and above its cost.

In the case under consideration, acid phosphate is superior to the mixed fertilizer, when $4.00 an acre is invested, since it returns $7.00 profit and the mixed fertilizer only $5.00. For the $4.00 application of fertilizer the true figure $7.00 varies less from the Liebig curve than it does from the one based on net returns over fertilizer cost, as indicated by line A B^1. The same is true for the 600 pound application, but not so for the heavier applications. It is obvious that curves C F and C D will coincide at some point. In the case under consideration, this is at the 1600 pound application. It is at this point, and this point only, that the assumption which is made as to returns from additional units of acid phosphate, in the common method of comparing financial returns, will apply. Consequently, it is not until 1600 pounds of acid phosphate have been applied that the assumed

net returns of $4.00 from acid phosphate hold true. Since this rate of application is in excess of that giving the highest net returns, the method applies neither to the 400-pound application under consideration, nor the 800-pound application from which the maximum net return from acid phosphate has been secured. It applies only to the 200 and 1600 pound applications.

Curves B E and C F indicate clearly that acid phosphate gives more satisfactory financial returns on the investment up to an application of 800 pounds to the acre than does the mixed fertilizer. With this 800-pound application, equal returns are secured. When the application exceeds 800 pounds, the mixed fertilizer produces better financial returns than the acid phosphate. It is perfectly evident that this true relation between the financial returns from the acid phosphate and mixed fertilizer could not have been determined from the results furnished by a single 200-pound application of each.

SUMMARY

It has been shown that the more profitable of two fertilizers, differing in cost, cannot be ascertained from the results of a single comparison of an equal rate of application of the two.

The method which makes comparisons on the basis of percentage return on the investment tends to favor the less expensive of the two treatments.

The common method of interpreting financial returns by comparing two single treatments based on net value of crops over the cost of fertilizer is generally in favor of the more expensive treatment. Particularly is this true where the fertilizer applications are small.

LITERATURE CITED

1. Hopkins, C. G. Soil Fertility and Permanent Agriculture. p. 252. Ginn & Co., Boston, Mass. 1910.
2. Thorne, C. E. Farm Manures. p. 179. Orange Judd Co., New York City. 1914.
3. Williams, C. G. Ohio Agr. Exp. Sta. Mo. Bul. 20, p. 250. 1917.

FALLEN TREES A CAUSE OF HUMMOCK FORMATION[1]

A. F. GUSTAFSON[2]

The method of formation of hummocks, sometimes called "bogs," in peat, muck, or other poorly drained areas, has long been a matter of academic interest to the writer. In Illinois, hummocks occur to the northward of latitude 41° N. approximately, while very few if any occur further south in that state. These formations occur in poorly drained places in New York outside of Long Island, in Iowa, Indiana and Ohio north of 41° N., and are well developed in Michigan and other northern states. The trampling of livestock[3] in pastures

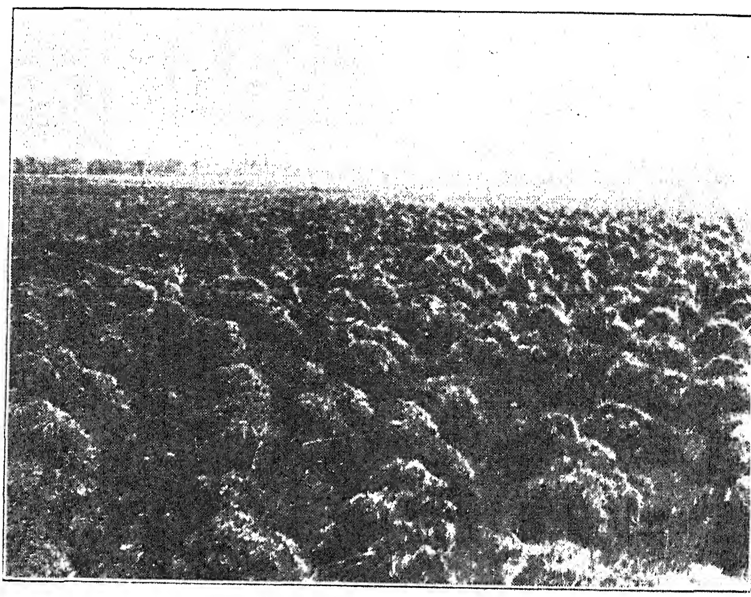


FIG. 1. These hummocks, 6 to 12 inches high, occur in poorly drained areas in northern Illinois.

has been advanced as a contributing cause. Livestock naturally walks in open, unobstructed places. If the stock trampled an area uniformly, their weight would tend to pack the soil material evenly rather than bring about any unevenness of surface. It appears that some obstruction, as a shrub or stump, the presence of a bunch of

[1]Contribution from Department of Agronomy, Cornell University, Ithaca, New York. Received for publication October 27, 1924.

[2]Extension Professor of Soil Technology.

[3]MOSIER, J. G., and GUSTAFSON, A. F. Soil Physics and Management, Lippincott and Co., Philadelphia, Pa. page 30. 1917.

grass or sedge, a piece of wood or possibly a difference in the consistency of the material under the surface, may help bring about hummock-formation. Freezing and thawing might raise small spots more than others, particularly where any sort of coarse material is present immediately below the surface. Once unevenness of surface has been produced, whatever the cause, the animals will trample between these raised spots, even tho but slightly above the general level. When the surface material is wet, which it is most of the year, in the natural, undrained state of this type of land, it is highly mobile so that the weight of the animals will tend to force the raised spots still higher. After this has continued for a period of years a condition similar to that shown in Figure 1 is produced.

After a muck area has been under cultivation and is later reseeded and pastured the hummocks reappear. So far as the writer is aware, there is no certainty that the hummocks would not have been reformed without pasturing. In the surface vegetation, certain grasses or sedges which grow in dense clumps may establish themselves and later give rise to hummocks. It is possible that other causes, such as the effect of freezing and thawing, may produce them.

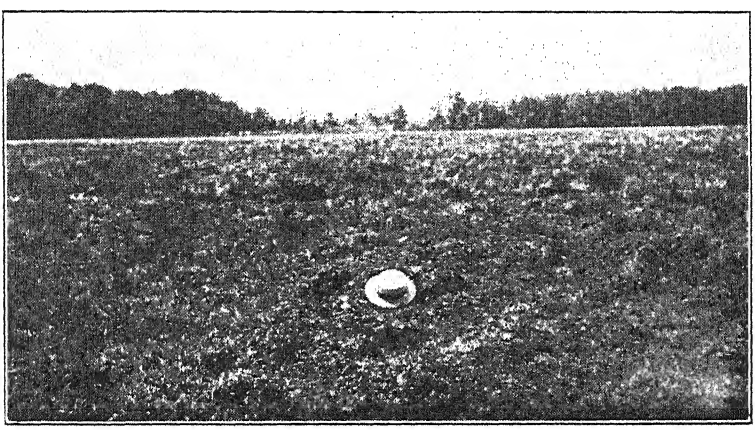


FIG. 2. Hummocks six to eight inches high in southern Michigan on muck cultivated ten years ago.

The photograph shown in Figure 2 was taken less than one hundred feet from the ditch which drains this part of a muck land pasture very thoroly. After a period of cultivation, the field was reseeded and has been pastured for ten years immediately previous to the taking of this picture.

In 1918, the writer chanced to observe, in the field adjoining the

pasture referred to above, a most interesting condition. The area on which the photographs from which the following figures were made is located about two miles east and somewhat south of the Eaton County courthouse at Charlotte, Michigan. Here, there is a distinct mode of hummock formation which is best set forth in figures three to eight following.

FIG. 3. An early stage of hummock formation due to a log.

In Figure 3, the upper part of a log is shown lying on a ridge fifteen to eighteen inches high which is indicated by the hat. All but the

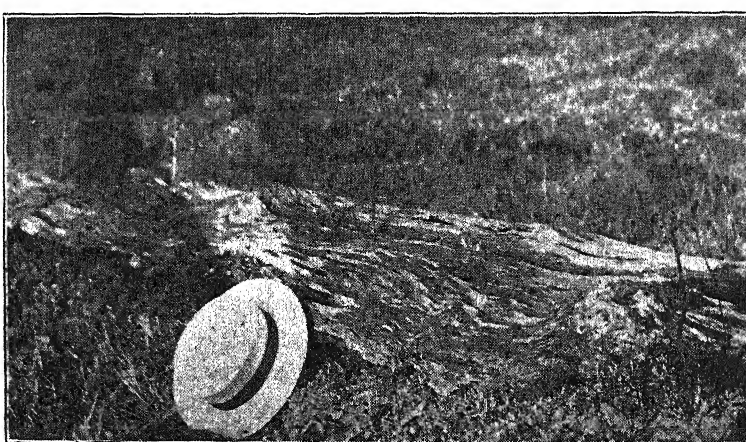


FIG. 4. A later stage of development showing the make-up of the hummock material.

outer portion of the upper half of the tree trunk has decayed completely, and constitutes the peat or muck forming the ridge shown in the figure.

Figure 4 shows a ridge composed of decayed wood, considerable pieces of which are visible, notably above the watch. There is on question that the material in the ridge, or elongated hummock, shown in this figure originated from wood decayed in the place it now occupies.

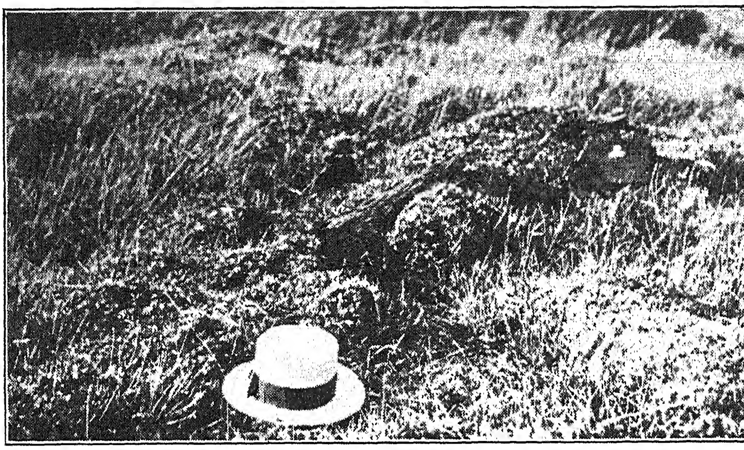


FIG. 5. An elongated hummock formed from a decayed log.

In Figure 5, there is shown a regular ridge with some vegetation on it. There may be noted two rather large pieces of wood, one be-

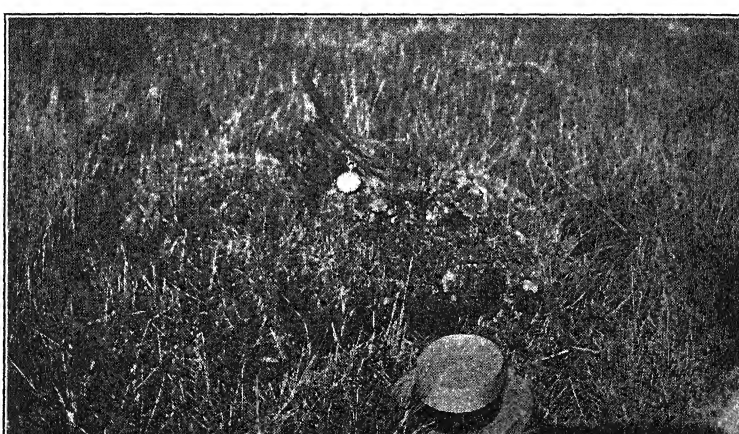


FIG. 6. A hummock formed from a stump.

yond the hat, the other beyond the camera case. These, presumably, are remnants of the original log from which the underlying ridge or hummock was formed.

The hummock shown in Figure 6 is made up of decayed wood. The part of stump back of watch is in its original position. Numerous hummocks in this field have this origin.

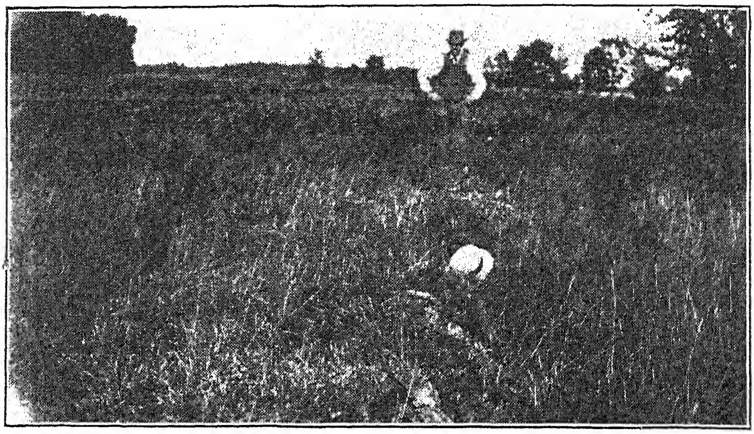


FIG. 7. A "log" hummock.

In Figure 7, there is shown what may be termed a "log" hummock. Some of the wood from the original log is still present. Several of these log hummocks were much longer than this one but unfortunately the picture of them is not clear enough to be reproduced satisfactorily.

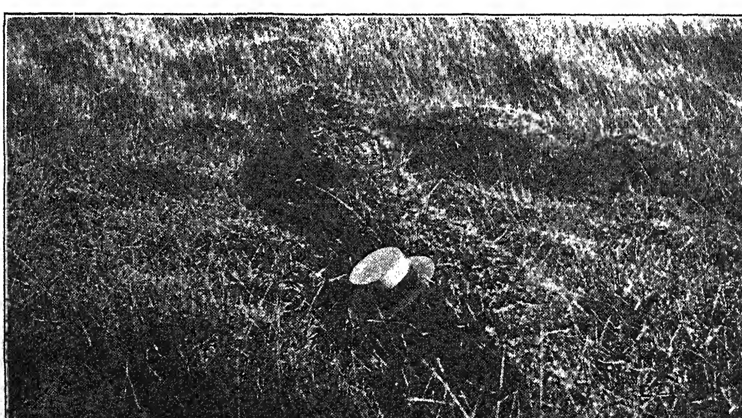


FIG. 8. Another "log" hummock.

In Figure 8, there is shown a different view with more or less rounded hummocks in a line. Here may be noted hummocks from a log which fell across the other one. These show the same origin as the preceding ones. The breaks are probably brought about by animals which make paths across these log hummocks. This eventually cuts the "log" up into a series of round or elongated hummocks as shown in these figures.

When a tree is uprooted by the wind a large quantity of soil material is carried up on the roots. This eventually becomes a heap at the side of the hole from which it was removed when the tree fell. This unevenness of surface may later become a hummock. When the tree dies and the trunk falls or whether the tree is uprooted in a storm, the log may be over grown by swamp vegetation, which on dying helps bring about "log" ridges or hummocks such as shown in these figures.

From these observations, it appears certain that the presence of logs and stumps has been an important factor, probably along with freezing and thawing and the trampling of livestock, in the formation of the hummocks in this particular field.

THE INHERITANCE OF GRAIN COLOR IN WHEAT[1]

H. K. Hayes and D. W. Robertson[2]

INTRODUCTION

The discovery by Nilsson-Ehle (4),[3] that grain color in wheat is dependent in some cases on cumulative factors, furnished a foundation for the present view that the inheritance of size characters can be explained in the same way as the inheritance of qualitative characters. The studies of Nilsson-Ehle, the Howards (3) in India, and Gaines (1) in this country have demonstrated the following breeding facts: 1. F_2 segregations of red-grained and white-grained plants in crosses between red-grained and white-grained wheats approximate the ratios of 3:1, 15:1 or 63:1 according to the number of factors for grain color contained in the red-grained parent. 2. White-grained segregates are obtained in some crosses between red-grained parental varieties.

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[2]Head of Section of Plant Breeding, Division of Agronomy and Farm Management, University Farm, St. Paul, Minn.,and Associate Agronomist, Department of Agronomy, Fort Collins, Colo., respectively.

[3]Reference by number is to "Literature Cited," page 789.

Studies in crop genetics lead to a knowledge of the genetic factors concerned in the development of characters of particular varieties. Such information assists materially in the planning of crop improvement studies. It is of importance therefore to know the number and behavior in inheritance of the genetic factors of those varieties which are to be used in crosses. The milling trade in the spring wheat section desires hard red-grained varieties of high milling quality. Previous studies by Harrington (2) show that Kitchener contains two independently inherited factors for red grain color, and that some strains of Red Bobs and Hard Red Calcutta contain two independently inherited factors for grain color, while others contain only a single factor.

The present note is a contribution to our knowledge of the genetic factors for grain color in Marquis, Minturki and Kanred.

EXPERIMENTAL WORK

CROSSES BETWEEN MARQUIS AND BOBS

These studies were carried on at the Minnesota agricultural experiment station. Bobs, a white-grained Australian variety, was crossed with Marquis, a red-grained variety, and segregation was studied in the F_2 generation. The results are presented in Table 1. Altho there was considerable variation in the degree of color of the red-grained segregates, it was impossible by inspection to differentiate between plants which were homozygous or heterozygous for grain color. Accordingly, the red-grained plants were placed in one group.

TABLE 1.—*The expected qnd observed segregation for grain color in the F_2 generation of reciprocal crosses between Marquis and Bobs wheats.*

Cross	Observed Red	Observed White	Total	Calculated Red	Calculated White	Deviation in numbers	P. E. in numbers	D/P.E.
Marquis x Bobs	263	27	290	271	18	9	2.8	3.2
Bobs x Marquis	255	18	273	256	17	1	2.7	.3

Probable errors in numbers were obtained from tables of probable errors of Mendelian ratios obtained from the Department of Plant Breeding of Cornell University.

The results in Table 1 indicate that red color in Marquis wheat is the result of two independently inherited factors, either one of which alone leads to the production of red color. The strain of Marquis may be said to contain the factors R R R^1 R^1, while Bobs contains the factors for white grain r r r^1 r^1. On this hypothesis, the F_2 of a cross of Marquis x Bobs would approximate a ratio of 15 red-grained plants to 1 white-grained plant.

A deviation as great as the one found in the Marquis x Bobs cross could be expected once in 32.36 times, while in the reciprocal cross of

Bobs x Marquis the observed ratio is very close to the calculated. Combining the reciprocal crosses, the deviation from the calculated 15.1 ratio is 10 and the probable error in numbers is 3.87. A deviation as great as this would be expected to occur once in every 12.58 trials.

CROSSES OF MARQUIS WITH MINTURKI AND KANRED

In 1921, the following crosses were made at the Colorado agricultural experiment station: No. 27, 28 and 31 were Minturki x Marquis and No. 59 was Kanred x Marquis. Both parents in each of the three crosses were red-grained varieties. In the F_2 generation, white-grained plants were found and the frequency of their occurrence was noted (Table 2).

TABLE 2.—*Comparison of the observed F_2 segregation with the expected F_2 segregation when three independently inherited factors are involved.*

Cross	Cross No.	Observed Red	Observed White	Expected 63:1 Red	Expected 63:1 White	Deviation from expected	Probable error	$\frac{D}{P.E.}$	Odds
Minturki x Marquis	27	513	12	516.8	8.2	3.8	1.92	1.98	2.49:1
Minturki x Marquis	28	316	7	318.0	5.0	2.0	1.50	1.33	1.7 :1
Minturki x Marquis	31*	615	13	618.2	9.8	3.2	2.10	1.50	2.28:1
Kanred x Marquis	59	966	12	962.7	15.3	3.3	2.61	1.26	1.53:1

*On close examination the Marquis parent proved to be Red Fife.

A ratio like the one obtained could be expected when three independently inherited factors for red grain color are involved, either one of which alone or in the presence of the other two leads to the production of red color. If it is assumed that Marquis has two factors for red color $R\ R\ R^1\ R^1\ r^{11}\ r^{11}$ and Minturki has a different factor $r\ r\ r^1\ r^1\ R^{11}\ R^{11}$, the F_2 generation from a cross between these varieties would approximate a ratio of 63 red-grained plants to 1 white-grained plant.

In comparing the observed with the calculated, there appears a small deviation. The chances of obtaining such a deviation are 1 in 3.49 trials for No. 27, 1 in 2.7 trials for No. 28, 1 in 3.28 trials for No. 31 and 1 in 2.53 trials for No. 59.

CONCLUSIONS

The Marquis wheat strain used in the White Bobs x Marquis cross has two independently inherited factors for red grain color. The Kanred and Minturki wheats used in crosses at the Colorado agricultural experiment station apparently have a third factor for red grain color which is independent in inheritance of the factors for grain color found in Marquis.

LITERATURE CITED

1. GAINES, E. F. Inheritance in wheat, barley and oat hybrids. Washington Agric. Exp. Sta. Bull. 135. 1917.

2. HARRINGTON, J. B. The mode of inheritance of certain characters in wheat, *In* Sci. Agric. June, 1922. pp. 319–324.
3. HOWARD, A., and HOWARD, G. L. C. On the inheritance of some characters in wheat. *In* Mem. Dept. Agr. India, Bot. Ser. 5:1–47. 1912.
4. NILSSON-EHLE, H. Kreuzungsuntersuchungen an Hafer und Weizen. *In* Lunds. Univ. Arsskr. N. F. Afd. 2, 7:3–84. 1911.

INHIBITION OF BUMPING IN THE DETERMINATION OF NITROGEN IN SOIL[1]

F. E. HANCE[2]

The procedure usually followed in the determination of nitrogen in soil is a lengthy operation involving considerable manipulation and the employment of a 10-gram sample.

In the digestion of the soil, with boiling sulphuric acid, bumping usually becomes violent and occasionally a container and its contents are lost by breaking. This may be avoided by reducing the weight of the sample, but, due to a low nitrogen content of most soils, such a reduction must be accompanied by greater accuracy in manipulation. To avoid the bumping and sputtering, which often results in a broken flask or the mechanical introduction of the undistilled liquid into the distillate, when the ammonia is being distilled off, the usual practice is to decant the clear digested liquor to a separate distilling flask followed by at least three successive washings of the silica residue by decantation. In addition to the consumption of time this procedure favors the introduction of error.

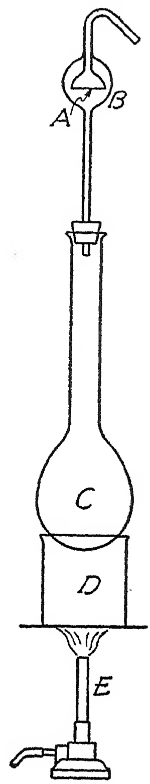
By the use of asbestos collars[3] the writer has been able to obviate the difficulties cited above in connection with the distillation process when the silica residue is present. The accompanying figure shows the assembly of a single distilling unit as used in this laboratory. The Kjeldahl flask C rests on an asbestos collar D which in turn is supported by a wire gauze. B is a glass condenser inclosing the spray arrestor A. When the flame of the Bunsen burner is directed upon the wire gauze the heating of the flask is accomplished by the upward passage of hot gases through the intervening asbestos collar. In this way local superheating is avoided at any point within the flask. Conse-

[1]Contribution from Department of Agronomy, Cornell University, Ithaca, New York. Received for publication October 31, 1924.

[2]Laboratory assistant.

[3]The asbestos collars may be prepared by cutting a rectangular strip of asbestos board and saturating it with a 20% solution of sodium silicate. While moist the board may be easily bent into the shape of a cylinder and fastened with wire thru holes punctured in the sides. When dry the collars become rigid and smooth and will stand hard usage and high temperatures without disintegration for several years.

quently boiling takes place evenly and quietly, the silica residue being continuously circulated in the swirl of the boiling mixture. The liquid contents of the flask may be concentrated to a very small volume with



the entire absence of bumping or sputtering. It has been found that 2 grams of nitrogen-free zinc dust added to the distilling flask, just following the addition of the syrupy sodium hydroxide, enhances the regularity of the boiling.

The accuracy afforded by this procedure has made it possible to reduce the weight of soil taken for analysis. In this laboratory 2.8 grams are being used. With this quantity of material but little bumping is encountered when the soil is digested with sulfuric acid.

The modifications here described have been followed successfully by the writer in the analysis of several hundred samples of soil accompanied with more accurate results obtained in shorter time and with less manipulation than was possible with the method as usually followed.

AGRONOMIC AFFAIRS

THE WESTERN SOCIETY OF SOIL MANAGEMENT AND PLANT NUTRITION

The Western Society of Soil Management and Plant Nutrition held its third annual meeting on June 24 and 25, commencing one day in advance of the regular session of the Pacific Division of the A. A. A. S. Twenty-five members attended and participated freely in the discussion of the papers.

Four half-day sessions and a business meeting were held and the following program was presented:

Soil Alkali and Soil Acidity

Replaceable bases in relation to soil acidity and the theory of replaceable bases. W. P. Kelley.

The relation of certain alkali salts to the growth of plants. A. R. Davis and D. R. Hoagland.

Tolerance studies for alkali soils in Idaho. R. E. Neidig and H. P. Magnuson.

The injurious after-effects of sorghum. J. F. Breazeale.

The Soil Solution

Nature and promise of the soil solution. J. S. Burd.

Secular and seasonal changes in the soil solution. J. S. Burd and J. C. Martin.

Some physiological aspects of soil solution investigations. D. R. Hoagland.

Soil structure and the soil solution. M. D. Thomas.

Replaceable bases in relation to the soil solution. W. P. Kelley.

Plant Nutrition

The stimulation effect of NaCl upon respiration and growth of wheat. A. R. Davis and L. J. Teakle.

The relation of potassium to the formation of diastase in wheat seedlings. A. R. Davis and J. L. Doughty.

The growth of plants under controlled environments. I—Electric light as a source of illumination. A. R. Davis.

The significance of the temporary depletion of certain essential mineral constituents in the soil on plant growth. W. F. Gericke.

Fertility experiments in Oregon. W. L. Powers.

The moisture equivalent as influenced by the amount of soil in this determination. F. J. Veihmeyer, O. W. Israelsen and J. P. Conrad.

Capillary potential measurements for the Greenville soil. Chester A. Chambers and Willard Gardner.

Routine testing of alkali soils in the laboratory (demonstration). P. L. Hibbard.

The soil profile as a basis for soil classification. C. F. Shaw.

Some chemical effects of sulphuric acid on alkali soils. C. D. Samuels.

The officers for the ensuing year are: D. R. Hoagland, University of California, Berkeley, *president;* H. P. Magnuson, University of

Idaho, Moscow, *vice-president;* M. D. Thomas, Utah Experiment Station, Logan, *secretary-treasurer.*

SOME FACTS CONCERNING THE 1924 CROP

The following statements concerning the conditions under which the 1924 crops of the United States were produced, harvested and marketed are compiled from several recent reports of the United States Department of Agriculture.

WEATHER

Contrary to the common comment, no single element of the weather has been wholly adverse. Combinations of moderately unfavorable elements have produced markedly unfavorable total conditions and effects in some localities. The past season has been quite similar to those of 1907 and 1917 in this respect. In the Ohio Valley wet weather delayed plantings and from that section eastward many crops were much later than usual, but killing frosts have generally been correspondingly later so that no serious damage has resulted.

COTTON

The crop has suffered less than usual from boll-weevil attacks. Some damage was caused by the cotton caterpillar; the infestation though general was light, but because of the lateness of the crop more than usual damage was caused. It is reported that there is little likelihood of competition from new cotton areas in foreign countries in the near future. On the other hand, a decrease of 8.6 percent in world mill consumption of cotton for the year ending July 31, 1924 is reported and a decrease of 8.4 percent in mill stocks at the close of the year, as contrasted with conditions for 1923. Approximately 2,090,000 tons of fertilizer were used on the 1924 cotton crop in the United States this year. This is a marked increase over that of any recent year.

WHEAT

The wheat acreage in 1924 for the northern hemisphere, excluding Russia, is estimated at 179,325,000 acres, as compared with 188,157,000 acres for 1923 and 168,966,000 acres as the 1909–1913 pre-war average. Russian production is reported to be on the increase, but still far short of pre-war figures. It is estimated that the total production in these same countries will be 2,700,000,000 bushels, compared with 3,000,000,000 bushels last year. The Canadian wheat crop for 1924 is estimated at 40.5 percent less than last year, a reduction of nearly 200,000,000 bushels. It is further estimated that American wheat growers will receive approximately $200,000,000

more for their crop this year than last year. Exports of wheat from the United States during August, 1924, exceed those of the same period last year by more than 1,100,000 bushels, a gain of 8 percent.

Preliminary estimates indicate an increase of 1,000,000 acres in plantings in Australia and the Argentine for the next crop. But if no more than average returns per acre are received, it is probable that the crop available for export will be somewhat less than last year.

WORLD PRODUCTION OF GRAIN CROPS

World production of wheat for 1924 is estimated to be at least 10 percent less than in 1923; rye, 16 percent less; and oats, 4 percent less. It is too early yet for accurate estimates on the corn crop, which is generally very late and likely to suffer severe frost injury.

MINUTES OF THE ANNUAL MEETING

The seventeenth annual meeting of the American Society of Agronomy was held at the New Ebbitt Hotel, Washington, D. C., on November 10 and 11, 1924.

MORNING SESSION, MONDAY, NOVEMBER 10

President M. F. Miller of the University of Missouri, called the meeting to order at 9:00 A. M.

The program consisted of a symposium on the subject of "Economic Relationships of Agronomy" under the leadership of Prof. E. G. Montgomery of the United States Department of Commerce, Washington, D. C. The following papers were given:

1. "Diminishing Returns in the Application of Agronomic Science to Field Practice."
   What are the Limitations in the Application of Agronomic Science to Practice?
   Prof. W. J. Spillman, Bureau of Agricultural Economics, U. S. D. A.
2. "The Economics of Fertilizer Use in the United States."
   Present Tendencies in Fertilizer Use and the Bearing on Future Production.
   Director S. B. Haskell, Massachusetts Agr. Expt. Station.
3. "The Economics of Liming."
   Present Day Tendencies and the Bearing on Future Production.
   Professor J. A. Slipher, Ohio State University.
4. "The Economic Interpretation of the Results of Fertility Experiments."
   The Relation Between Gross Increase and Net Profits.
   Professor E. L. Worthen, Cornell University.
5. "Changes in Standards of Living to Counterbalance Increasing Population."
   What Changes in Food Consumption are Possible Without Materially Lowering Present Day Standards?
   Professor E. G. Montgomery, Bureau of Foreign and Domestic Commerce.

At the conclusion of the program President Miller announced the following committees: *Nominating*, S. B. Haskell, C. R. Ball, and L. E. Call; *Auditing*, M. J. Funchess and C. E. Helm; *Resolutions*, C. E. Leighty, and E. Truog.

AFTERNOON SESSION, MONDAY, NOVEMBER 10.

The meeting was called to order at 2:00 P. M. by President Miller and the program on "Agronomic Observations in Foreign Lands" was given as follows:

1. "Varieties of Indian Corn in South America."
   Prof. F. D. Richey, Bureau of Plant Industry, U. S. D. A.
2. "The Great Soil Groups of Brazil and Argentina and Their Possible Agronomic Values."
   Dr. C. F. Marbut, Bureau of Soils, U. S. D. A.
3. "The Collecting of Cereal Varieties in Africa and Asia."
   Dr. Harry V. Harlan, Bureau of Plant Industry, U. S. D. A.
4. "The Ecology of the Grassland of the Bombay Deccan."
   Prof. L. B. Kulkarni, College of Agriculture, Poona, India.

EVENING SESSION, MONDAY, NOVEMBER 10.

The annual dinner and business meeting of the Society was held at 7:00 P. M. in the New Ebbitt Hotel.

The presidential address on the subject "Agronomic Science and Increased Production" was delivered by Prof. M. F. Miller. (See pp. 757-767)

Dr. R. W. Thatcher, Editor, then read his report, which upon motion was adopted. The report follows:

REPORT OF THE EDITOR

I think that the membership of the Society will generally agree that the JOURNAL has this year been bigger and better in nearly every way than it has ever been before. Volume 16 (for 1924) will contain approximately 830 pages. This is an increase of 54% over the number of pages in Volume 15, which, in turn, contained an increase of over 50% over the number of pages in the volume of the preceding year, or a total increase in pages published of over 130% in the two years since the increase in dues and the admission of paid advertising in the JOURNAL went into effect. The transfer of the contract for publishing the JOURNAL to a new firm, beginning with the first number of Volume 16, has resulted in some additional savings in the cost of printing and distribution, with no loss, and perhaps a slight gain, in the quality of the mechanical work on it. Further, it was possible this year to follow out the plan, for which a desire had been frequently expressed, of publishing the various papers of the several symposia each complete in a single issue of the JOURNAL. These issues constitute very comprehensive and generally satisfactory surveys, or reviews, of the current knowledge and present status of the problems which were discussed in the respective symposia. The practice of devoting alternate issues to the publication of contributed papers and symposia papers, respectively, has resulted in some delay in the appearance of the latter, but has seemed to be a procedure which was generally fair to the authors of the two kinds of papers.

The total expense for printing the first ten issues of Volume 16 and the reprints of articles appearing in them has been \$3667.11. For the extra reprints sold to authors, there was received \$458.95. Advertising in these issues brought an income of \$680.55. Hence, the net cost to the Society of these ten issues was \$2527.61, or an average of \$252.76 per issue, as contrasted with \$186. per issue last year. But these ten issues contained a total of 688 pages instead of the 432 pages in the corresponding issues last year, so that the net cost per page issued this year was only \$3.67, as contrasted with \$4.30 per page last year. This decreased cost is partly due to the relatively less cost of handling the larger issues,

partly to a somewhat more favorable contract with the publisher than we had before, and partly to savings in transportation costs, etc., by having the JOURNAL printed and distributed from the same city in which the editorial office is located.

The editor freely acknowledges the many editorial sins, both of omission and of commission, which have occurred during the year. He is as fully cognizant of these as are the members of the Society, some of whom have called these matters to his attention, while doubtless many others might have done so. He offers, not as a justification but as an excuse, the pressure under which the editorial work must be done in addition to his regular professional duties. This is a difficulty from which this Society, in common with many others which must depend upon voluntary, unpaid editorial service for their Journals, suffers. If the editorial work of the JOURNAL of this Society continues to increase, it will soon be beyond the ability of any single voluntary editor to take care of it. The present editor now wishes to express his keen appreciation of the generally kindly way in which members of the Society have accepted his sometimes rather drastic editorial treatment of their manuscripts in the preparation of them for printing in the JOURNAL. This is never done in any spirit of criticism, or from personal preference, but always solely for the purpose of preserving the standards of form, diction, etc, which have been established by former editors.

During the year which ended October 31, 1924, the editor received a total of 138 manuscripts of articles of all kinds. As compared with the total of 71 which were received during the same period last year, this is an increase of 95%. This increase seems to indicate that the members of the Society are anxious to make use of the facilities for fairly prompt publication which the JOURNAL now offers.

The 138 manuscripts which were received included 42 papers which had been read as part of the several symposia at the different meetings of the Society, 4 committee reports, 12 book reviews, and 80 contributed articles. Of these, 120 will have appeared in the JOURNAL when the November issue comes from the press, 12 have been returned to their authors for one reason or another, and 6 remain on hand for later publication, probably in the December issue. Contributed articles have generally appeared in the JOURNAL within not to exceed four months from the date of their receipt by the editor. Symposia papers have necessarily been a little longer delayed in some cases, since these all accumulate at practically the same time early in the year. In general, it may be said, however, that the JOURNAL is now offering about as prompt publication of material as it is possible for any scientific publication to do, even under the most favorable circumstances.

It may be of interest to the members of the Society to note the institutional origin of these papers. Except in the case of certain invitation papers at symposia, articles which were published in the JOURNAL came almost wholly from members of the Society. The practice of accepting papers only from members has been deviated from only three or four times during the year, and then only for some very good reason. The institutional connection of the authors of the papers which have appeared in the JOURNAL this year is as follows:

University of California	3	N. Y. State Agric. Expt. Station	8
Colorado Agricultural College	1	North Carolina A. & M. College	2
Connecticut Agricultural College	1	North Dakota Agric. College	3
Georgia A. & M. College	1	Ohio Agric. Expt. Station	3
University of Illinois	7	Ohio State University	5
Purdue University	2	Oklahoma A. & M. College	4
Iowa State College	4	Oregon Agricultural College	2

Kansas Agricultural College	5
University of Kentucky	2
University of Maryland	1
Massachusetts Agric. College	2
Michigan Agricultural College	3
University of Minnesota	5
University of Missouri	3
University of Nebraska	2
Rutgers College	4
Columbia University	1
Cornell University	19
Rhode Island Agric. College	2
University of Tennessee	2
Texas A. & M. College	1
Utah Agricultural College	3
Virginia Polytechnic Institute	4
University of West Virginia	2
University of Wisconsin	5
U. S. Department of Agriculture	23
Canadian Institutions	1
Commercial Companies	6

Many institutions at which agronomic work is in active progress are not included in the above list, and it is probable that as interest in the JOURNAL grows and knowledge of the publication facilities which it offers becomes better disseminated, there will be an increasing number of papers offered. Just at present, however, the volume of material offered is about as great as could be handled with the funds which are available from the membership dues, subscriptions, and advertising income. It is probable, however, that the income may grow about as fast as the future offerings of material for publication increase.

The income from advertising this year has not been as large as was hoped for at the outset. However, it has paid the salary of the assistant editor and advertising manager and nearly $500 in addition, at very slight additional expense for publication, and, so far as the editor can judge, has in no way detracted from the appearance or usefulness of the JOURNAL. Several annual contracts are now in force and it seems probable that, with the beginning of a new calendar year, others may be secured. It is, therefore, recommended that the present plan be continued, both as to the employment of an assistant editor and advertising manager and to the admission of advertising in the JOURNAL.

It would appear that the JOURNAL has reached a fairly stable condition. The increasing number of subscriptions from libraries, especially those of foreign countries, indicates that it is now generally recognized as one of the standard scientific publications of the world, and will probably have a steadily growing subscription list. The membership of the Society will undoubtedly fluctuate from time to time, depending upon the activity of the officers in pressing new membership campaigns. It would seem, however, that the suitable material and the income which will probably be available will make it possible to print a regular volume of twelve issues in a total of 800 to 1000 pages each year without any marked change in policy.

However, several suggestions for improvement in the JOURNAL have come to the editor's attention, and he now ventures to call them to the attention of the Society, not as definite recommendations but as matters which may possibly be of interest and perhaps needing attention.

The first of these is the proposal to unite the JOURNAL of this Society with other journals which are now being issued which deal with matters falling in the general field of agronomy. This would theoretically be very desirable, and it is possible that some practicable plan to bring it about could be worked out. The proposals which have thus far come to the editor's attention, however, have seemed to him to offer advantage chiefly to the other journals concerned and to add little to the possibilities of our own. But it may be that a plan could be perfected which would be of real economy and usefulness to the members of this

Society, by decreasing the number of journals to which they would need to subscribe in order to keep abreast with agronomic literature. But, thus far, no definite proposal which would insure this desired result has come to the editor's attention.

The second is that our JOURNAL should become the avenue of publication of papers for other associations or societies in the general agronomic field. This seems to the editor to be highly desirable from every standpoint and to offer no serious difficulties so far as the editorial aspects of the matter are concerned. The problem here is that of correlation of Society efforts and membership adjustments. These are matters which properly come within the jurisdiction of the Executive Committee for consideration and settlement.

A third possibility is that of introducing an abstract department in the JOURNAL. It would seem that such a feature might render a very real service to the readers of the JOURNAL, unless this need is already adequately met by the several agronomic sections of the Experiment Station Record, which is available to a large proportion of the members of this Society. It is possible that if an abstract department were maintained in the JOURNAL, somwhat mcre complete and detailed abstracts could be made than are possible in the Experiment Station Record. But to undertake such a department would involve (in addition to financial considerations) the creation of a corps of abstract editors, the establishment of an exchange list of journals, and perhaps other details which would need to be carefully considered before the venture were undertaken. In view of these facts, it is the judgment of the present editor that the matter of an abstract service in the JOURNAL may well be postponed for future consideration, but he has felt that it would be wise to call attention to it at the present time.

Fourth, several members of the Society have expressed the wish that more material which deals with the different phases of extension work in agronomy might appear in the JOURNAL. With this wish the present editor is wholly sympathetic, since it is his belief that the JOURNAL should serve all types of professional workers in the agronomic field. The only thing that he can do, however, is to point out that the pages of the JOURNAL are now open to such material, and it is necessary only that suitable articles be prepared and submitted by extension agronomists in order to secure the desired result.

In conclusion, the editor wishes to express his hearty appreciation of the active cooperation of many members of the Society in strengthening the quality of the material which has become available to the JOURNAL in recent years. He wishes also to voice his grateful recognition of the very prompt and efficient services of the Secretary-Treasurer, Dr. Brown, whereby the business matters of the JOURNAL are kept in such a highly satisfactory condition.

R. W. THATCHER, *Editor*.

The report of the Treasurer was read and upon motion was received and referred to the Auditing Committee.

REPORT OF THE TREASURER

I beg to submit herewith the report of the Treasurer for the year November 1, 1923—November 1, 1924:

Balance, last report, general fund	$1,002.34
Balance, last report, lime association fund	147.20
Total balance, last report	$1,149.54

RECEIPTS

Dues, 1924	$2,364.45	
Dues, 1924, new	410.05	
Dues, 1923	18.50	
Dues, 1925	64.00	
Subscriptions, 1924	641.13	
Subscritpions, 1924, new	147.15	
Subscriptions, 1922 and 1923	236.00	
Subscriptions, 1925	20.50	
Advertising income	862.91	
Reprints sold	434.60	
Journals sold	275.80	
Total receipts		$5,475.09
Total income, 1924		$6,624.63

DISBURSEMENTS

Printing the JOURNAL—reprints, etc. (13 issues, Oct. 1923—October 1924, incl.)	$4,854.24	
Salary Bus. Mgr. & Asst. Editor	300.00	
Miscellaneous printing (Letterheads, envelopes, programs, etc.)	108.25	
Stamps (secretary and editor)	95.00	
Freight, express and drayage	40.64	
Miscellaneous items (Refunds, returned checks, badges, etc.)	80.25	
Total disbursements		$5,378.96
Balance on hand		$1,245.67
Balance—Lime Assoc. Fund		$ 147.20
Balance—General Fund		$1,098.47
Total balance on hand		$1,245.67
Total Income		$6,624.63
Disbursements		$5,378.96
Balance		$1,245.67

Respectfully submitted,
P. E. BROWN, *Treasurer.*

Audited, November 10, 1924
M. J. FUNCHESS,
C. A. HELM,
Auditing Committee.

The Secretary then presented his report which was adopted. The report follows:

REPORT OF THE SECRETARY

I beg to submit herewith the annual report of the Secretary.

Membership.—There has been an increase in the membership in the Society during the year, which tho small, is nevertheless encouraging. The changes in the membership are shown in the following figures:

Membership, last report		561
New members	81	
Reinstatements	8	
Total increase	89	
Resignations, 1924	20	
Deaths	2	
Dropped, 1924	51	
Total decrease	73	
Net increase	16	16
Present membership		577

Comparing these figures with those presented last year, it will be noted that there was a decrease this year of only 73 as against 227 last year. Fifty-one were dropped for non-payment of dues, as compared with 182 last year. Eighty-one new members were added this year, as against 76 last year. The net increase in membership this year was 16 compared with a decrease last year of 82.

It seems evident that the Society is on a good sound basis and it is very encouraging to note the large number of new members and the small number of members dropped for non-payment of dues or lack of address. Probably such a shifting membership is to be expected in any organization of as large a total membership. The support of all the members is constantly needed in order that there may be a goodly increase in members each year and a minimum in members dropped.

Representatives of the Society at the various colleges and experiment stations have given invaluable help during the year and it is due to their aid that the membership figures are so encouraging. I would recommend that the Society formally express its appreciation of the loyal support of all those members who have taken time to secure new members and to induce old members to remain in good standing.

The list of membership by states is as follows:

Alabama	3	Kentucky	6	North Dakota	8
Alaska	1	Louisiana	3	Ohio	31
Arizona	3	Maine	2	Oklahoma	3
Arkansas	8	Maryland	11	Oregon	7
California	20	Massachusetts	4	Pennsylvania	13
Colorado	5	Michigan	10	Rhode Island	2
Connecticut	8	Minnesota	20	South Carolina	6
Delaware	4	Mississippi	4	South Dakota	8
Dist. of Columbia	51	Missouri	17	Tennessee	5
Florida	4	Montana	6	Texas	17
Georgia	6	Nebraska	12	Utah	5
Idaho	4	New Hampshire	2	Vermont	1
Illinois	26	New Jersey	6	Virginia	6
Indiana	16	New Mexico	4	Washington	8
Iowa	37	New York	38	West Virginia	6
Kansas	25	North Carolina	4	Wisconsin	16

Wyoming	3	Denmark	1	Philippine Islands	2
Africa	2	England	11	Porto Rico	1
Australia	1	Egypt	1	Russia	2
Brazil	4	Haiti	1	South America	2
British West Indies	1	Hawaii	4	Spain	1
Canada	17	India	1	Sweden	2
China	5	Japan	7	Turkey	2
Cuba	2	Mexico	2		
		Total			577

In several of these states, while the figures are small, there is a 100% membership. In others, there are many agronomists who are not members. Undoubtedly during the coming years, a larger percentage of agronomists everywhere will be induced to affiliate themselves with their special technical society.

Subscriptions.—There has been a considerable increase during the year in subscriptions. Thirty-two new subscriptions have been secured and the total number of subscriptions is now 194, compared with 171 reported last year, a net increase of 23. Several of the subscriptions are for more than one copy of the JOURNAL. If each is listed separately, the total would be 202. A comparative figure to this was not given last year. Twenty-nine were dropped but thru the efforts of the Editor, the President and the Secretary, with the aid of the local society representatives, 20 of this number were reinstated and a large amount of arrearage in subscriptions was collected, as shown in the Treasurer's report.

Finances.—The Treasurer's report shows the sound financial condition of the Society at the present time. The total collections for dues has amounted to $2,857.00. The total income from subscriptions was $1,044.28. The remainder of the income has come from advertising, the sale of reprints and the sale of back numbers of the JOURNAL.

Thirteen issues of the JOURNAL have been published and paid for and the balance on hand of over $1200 is much more than sufficient to handle the cost of the two remaining issues for 1924.

The advertising income amounted to $862.91 and there is still a considerable amount which will be collected. The Editor and Business Manager have been most successful in securing advertising and the income from this source is of much help in keeping the finances of the Society sound.

The cost per issue for the JOURNAL should be calculated on the Editor's figures which include some bills outstanding. His figures for advertising income and reprint sale will be different than those given in the Treasurer's report. He has calculated the cost per issue at $252.76. The figure from actual income to date is $296.

There are a few outstanding dues to be collected, all from foreign members. Practically all of these will be secured. More time is allowed for these members, but all accounts will be closed before the end of the year. Several statements have been sent out to members before any were dropped and this practice has aided materially in keeping such a large number in good standing.

The expenditure for stamps will indicate the amount of mail sent out from the Secretary's office and from the Editor's office. A considerable portion of this total should be charged against the receipts from the sale of JOURNALS but at least three-fourths may be estimated as utilized for letters, bills, receipts, and notices. No attempt has been made to estimate the amount of correspondence from the Secretary's office but it is certainly very large.

Journals Sold.—Many requests for back numbers of the JOURNAL have been met during the year and the income from this source amounted to $275.80. Several sets have been sold complete except for Volume 8, only one number of which is still available. The number of the early volumes of the JOURNAL is becoming small and very soon many will be out of print. Following previous custom, members have been supplied with the back numbers of the JOURNAL at reduced prices; while agencies have been allowed the usual 10% discount.

Meetings.—Reports of the meetings of the Society during the year have been given and no complete report need be made here.

The winter meeting was held with the A. A. A. S. at Cincinnati on December 28, 1923, and the program consisted of symposium on "Research on Crop Plants Fundamental to Economic Problems" arranged by Dr. C. R. Ball. The meeting was a most enjoyable and successful one in every way.

The summer meeting of the Corn Belt Section of the Society was held at the Iowa State College in August. There was a large attendance. The program consisted mainly of an inspection and study of the experimental work in farm crops and soils which is being carried out by the Iowa Agricultural Experiment Station. The next summer meeting will be held at the Michigan Agricultural College.

The Western Agronomists met at Laramie, Wyoming, and their meeting proved most successful. A report of the program followed at that meeting has been published.

The annual meeting was announced to all members by a post card and the program has been distributed to the entire membership. Dr. R. A. Oakley of the Bureau of Plant Industry has had charge of the arrangements and the Society is much indebted to him for taking care of local arrangements.

The Society is sponsoring the program to be given at the International Hay and Grain Show in Chicago. The arrangements for this meeting are being taken care of by Prof. A. J. Ogaard.

No separate winter meeting will be held this year with the A. A. A. S., but a joint program with Section O of that Association is being arranged for the afternoon of Wednesday, December 31, at Washington, to be followed by a joint dinner with Section O and with the other agricultural societies affiliated with the Association.

Appointments.—The Committee appointments made by President Miller have been announced. In addition to these Prof. L. E. Call was appointed to the Council of the A. A. A. S. as the Society is now entitled to two representatives. Special sub-committees on the registration of oats, barley and wheat were also appointed. Dr. C. R. Ball was appointed as our representative on a joint committee with the phytopathologists on the Terminolgoy of the Physiologic Entities in Fungi.

In conclusion I wish to express my apppreciation of the hearty support given me by the officers and members of the Society. I am particularly indebted to President Miller and Editor Thatcher.

Respectfully submitted,

P. E. BROWN, *Secretary.*

Dr. C. V. Piper presented the following report of the Committee on Terminology:

Your Committee on Terminology begs leave to report that it has now assembled a very extensive list of agronomic terms. It hopes during the coming year to

present tentative reports upon many groups of terms and make recommendations as to their use or avoidance. Four papers are in the possession of the Committee, but it has not been deemed wise to publish them until the assembling of all terms in each of the many categories has been completed. Your Committee begs further indulgence and hopes that the progress it will make during the coming year will justify the long-sustained patience of the Society.

C. V. PIPER, *Chairman* C. R. BALL H. L. SHANTZ

Prof. E. F. Gaines presented the report of the Committee on Varietal Standardization which upon motion was adopted. The report follows:

REPORT OF VARIETAL STANDARDIZATION COMMITTEE.

In an effort to assist in the standardization of crop varieties your committee has in previous reports advised the adoption of a uniform plan for the registration of varieties of wheat, oats and barley on the basis of actual performance test in replicated trials which have been conducted for a series of years. A special committee has devised a plan of procedure which has been adopted by your Society. Three committees of three each for the registration of the three crops have been appointed and the Office of Cereal Investigations has agreed to undertake the duties of caring for the register and the necessary identification specimens. The committee on varietal standardization wishes to affirm its belief in registration as a means of furnishing a list of standard varieties and strains and thereby making available to all agronomists the names of varieties of especial value for particular regions. It wishes to urge the desirability of getting the actual work of registration under way. Before new varieties can be registered it is necessary that the standard varieties be listed. May we not have the support of all agronomists in this important undertaking?

After having established a satisfactory scheme of registration for the small grain crops your committee will then be in a position to promote the registration on the basis of merit of other crop plants.

It appears certain to your committee that registration will be an important aid to varietal standardization for by the plan adopted special strains of known high performance ability will be registered and will then naturally be adopted as the standard for particular varietal trials. There are cases, however, when particular varieties or strains of crops will be used in important research studies where the strains in question will not necessarily have been registered. There is a necessity for a better method of identification of such material. As a further means of varietal standardization it is urged that all agronomists describe with care the varieties or strains used in each particular study and identify such material by means of some identification number commonly understood by all agronomists. For cereal crops the use of a correct C.I. number would be of value. In cases where C.I. numbers are used as a means of identification for commercial non-pedigreed varieties it is further desirable that pure line identification numbers be used. A careful description of the variety used with a statement of its pedigree is almost necessary to a correct understanding of the behavior of this variety.

As an aid to identifying varieties in publications we recommend in addition to State numbers the C.I. numbers when available.

H. K. HAYES, *Chairman*, A. B. CONNER,
J. H. PARKER, R. G. WIGGANS,
R. J. GARBER, J. A. CLARK,
E. F. GAINES, H. S. HASTINGS.
GEO. STEWART,

The report of the Committee on Standardization of Field Experiments was given by Prof. C. A. Mooers and was adopted, it being understood the reprints of the report with the additional bibliography would be printed for distribution by the Secretary with the report submitted one year ago. The report follows:

REPORT OF COMMITTEE ON THE STANDARDIZATION OF FIELD EXPERIMENTS.

Your committee desires to report that in their judgment no changes in the standards adopted last year should be made at this time. It seems wise to give them a thorough trial before suggesting any specific changes.

However, there are a number of problems of considerable importance which are not considered in the standards, or concerning which very little experimental data are available. It seems worth while to call attention to some of these, in order to stimulate the assembling and publication of data that may have accumulated at various institutions and to encourage further experimental work. The committee believes that the following problems are especially worthy of consideration.

1. The importance of competition. The fact that competition may be an important factor has been clearly demonstrated. To eliminate it, however, requires extra land and, in some cases, involves much extra expense. It is believed that in some cases its effect may be made of very little importance by grouping varieties and strains according to time of maturity, habits of growth, etc. This possibility seems worth investigating.

2. Additional experimental data should be secured pertaining to the effect of replication in reducing experimental error, taking into consideration the extra land required and the greater opportunity for soil variation.

3. The relative accuracy of different methods of planting small grain nurseries, including a comparison of (a) single row and multiple row plots and (b) hand planting versus machine planting.

4. Economical methods of testing the large numbers of strains (selfs and hybrids) of corn so necessary in modern methods of breeding this cereal. This problem relates especially to the minimum size of plot or length of row and the importance of competition.

5. The place of pot and tank experiments (in the open and in greenhouses) in agronomic experimentation and their relation to field experiments.

6. Sources of error in pot and tank experiments.

The committee wishes to express its obligations to Professor L. J. Stadler for nearly all of the very complete list of references appended to this report. Professor Stadler has made an exhaustive search of the literature and has found some old and very interesting papers to be added to the previously published list.

The committee recommends that the entire bibliography relating to the standardization of field experiments and the standards adopted at the last annual meeting be published as a reprint of the JOURNAL for the benefit of those especially interested.

PFEIFFER, T. Die Bedeutung der Wahrscheinlichkeitslehre für die Landwirtschaft, dargelegt an der Hand von Sortenenbauversuchen. *In* Fühlings Landw. Ztg. 59:569. 1910.

PFEIFFER, T. Die Anwendung der Wahrscheinlichkeitslehre auf Fragen der Landwirtschaft. *In* Fühlings Landw. Ztg., 67:297–303. 1918.

REMY, T., and SAMEL, P. Die Bedeutung der Wahrscheinlichkeitslehre für die Landwirtschaft, dargelegt an der Hand von Sortenanbauversuchen mit Zuckerruben. *In* Blät. fur Zuckerrübenbau, 18:41–45; 56–61 and 69–74. 1911.

RICHEY, F. D. Adjusting yields to their regression on a moving average as a means of correcting for soil heterogeneity. *In* Jour. Agr. Res. 27:79–90. 1924.

RODEWALD, H. Zur Anwendbarkeit der Methode der kleinsten Quadrate. *In* Fühlings Landw. Ztg. 67:303–312. 1918.

RODEWALD, H. and QUANTE, H. Die Haferanbauversuche der Deutschen Landwirtschaftlichen Gesellschaft. *In* Arb. der Deut. Landw. Gesell. 125:1–51. 1907.

RODEWALD, H. Die Anwendung der Ausgleichsrechung bei der Ausnutzung von feldmässigen Anbauversuchen. *In* Mitt. der Deut. Landw. Gesell. 22: 353–355. 1907.

RODEWALD, H. Die Mitscherlichsche Ausgleichsrechnung zur Ausschaltung der Ungleichheit des Bodens auf den Versuchsfeldern. *In* Fühlings Landw. Ztg. 69:371–378. 1920. (Abs. in Bull. Agr. Intell. & Pl. Dis., 12:250.)

ROEMER, T. Vergleichende Anbauversuche. *In* Fühlings Landw. Ztg. 65:258–271. 1916.

ROEMER, T. Ueber die Technik der Feldversuche. *In* Fühlings Landw. Zeit. 67:102–114. 1918.

ROTMISTROV, W. Die Grundprincipien des Feldversuchs. *In* Russ. Jour. Expt. Landw. 4:645–672. (Abs. in German, pp. 672–673. 1903.)

ROTMISTROV, W. Drei Methoden zur Bestimmung der Ergebnisse von Feldversuchen. *In* Russ. Jour. Expt. Landw. 5:145–166. (Abs. in German p. 167. 1904.)

RUMKER, K. Massenanbauversuche mit Futterrüben eine neue Methode der Vorprüfung. *In* Mitt. Landw. Inst. der Küniglichen Universitât Breslau, 4:873–895. 1909.

SCHARNAGEL. Zur Technik der Stammes und Sortenprüfung in Zuchwelschaften und Versuchstationen. *In* Mitt. Deutsch. Landw. Ges. 39:58–61. 1924. (Abs. in Bot. Abs. 13:708. 1924.)

The Committee on Standardization of Teaching Work in Crops and Soils submitted a report from Dr. J. O. Morgan, Chairman of the Subcommittee on Crops, which was read by the Secretary. The report was adopted.

REPORT OF SUBCOMMITTEE ON STANDARDIZATION OF TEACHING WORK IN FIELD CROPS.

The following are some of the data secured as a result of the questionnaire sent out to teachers of farm crops relative to the standard course in field crops.

Replies were received from agronomists at 39 of the Land-grant Colleges. Of these, 24 state that they have adopted the standard course in field crops as recommended by the committee, with, of course, such slight modifications as are found necessary due to the difference in local conditions. These 24 institutions are: California, Colorado, Connecticut, Delaware, Florida, Illinois, Indiana, Kentucky, Kansas, Louisiana, Massachusetts, Michigan, Minnesota, Missouri, New Jersey, New Mexico, New York, North Carolina, Tennessee, Vermont, Virginia, West Virginia, Wisconsin, and Texas.

The 15 institutions that have not adopted the course are: Alabama, Arizona, Idaho, Iowa, Maryland, Georgia, Montana, Nevada, North Dakota, Ohio, Pennsylvania, South Carolina, South Dakota, Washington, and Wyoming.

Of these 15 institutions, the workers at Arizona, Iowa, Pennsylvania and South Carolina state that they are in sympathy with the course and hope to be able to get it adopted in their institutions within the next year or so. The institutions

that have not adopted the course give as their chief objections to the course that it is too general and contains information that rightly belongs to other departments, or that it simply doesn't suit their conditions. Some of them state that they prefer the individual treatment of field crops to the general or topical treatment.

Of the 24 institutions that have adopted the course, 9 give the course in the freshman year, 9 in the sophomore year, 2 in the junior year, 2 in the freshman or sophomore year, and 1 in the junior or senior year. 8 institutions give the course as a 3–2 course (3 hours lecture or recitation and 2 hours laboratory). 5 institutions give the course as a 2–2 course, 2 as a 3–4 course, 1 as a 2–4 course, 1 as a 2–1 course, 1 as a 1–2 course, 1 as a 2–3 course, 1 as a 3–6 course, and the other 3 give the work almost entirely as a laboratory course, although they state that part of the time is used for lectures and recitations.

18 of the institutions that have adopted this course require it of all agricultural students. 3 institutions state that the course is elective and the other 2 institutions did not say whether or not the course was required.

Practically all of the institutions having adopted this course state that it has proved satisfactory with certain modifications. This applies particularly to the lectures or recitations. Workers at a number of the institutions which adopted the course state that they have not been able to follow very closely the outline of laboratory studies as prepared by the committee on laboratory studies for the fundamental course in field crops, but those at the majority of institutions state that the outline is being followed rather closely, with, of course, certain modifications. A few state that they have been able to correlate the lectures and laboratory work, but most of them have found this rather difficult for the reason that certain laboratory exercises have to come at definite times, particularly field laboratory work.

It appears that the showing made by the standard course in field crops is very gratifying, and that within just a few years all of the institutions will be giving a fundamental course quite similar to this one.

J. O. MORGAN, *Chairman Sub-Committee on Teaching Work in Field Crops.*

Dr. J. G. Lipman stated that inasmuch as certain revisions of the Constitution had been proposed, which vitally affected the function of the committee, the Special Committee on Honorary Members, Fellows and Publications, had no report to offer.

The report of the Advisory Committee to the National Research Council was presented by Dr. J. G. Lipman. Upon motion the report was adopted. The report follows:

REPORT OF THE ADVISORY COMMITTEE FROM THE AMERICAN SOCIETY OF AGRONOMY TO THE NATIONAL RESEARCH COUNCIL.

In behalf of your committee, the chairman begs leave to report concerning certain of the activities of the committee since the last meeting of the Society. This report has to do largely with the participation of representatives of the Society in the Fourth International Conference of Soil Science; with the progress of investigations on the salt requirement of agricultural plants; and the research on the oxidation of sulphur in soils.

THE INTERNATIONAL CONFERENCE OF SOIL SCIENCE.

The First International Conference of Soil Science, or Agro-Geology as it was then designated, was held in Budapest, Hungary, April 14–24, 1909. The con-

ference was organized at the invitation of the Royal Geological Institute of Hungary and the meetings were held under the patronage of the Secretary of Agriculture. The program dealt with (a) general papers on agro-geology; (b) a consideration of soil types in different countries as based on available information; (c) projects for establishing a general classification of soils; (d) research methods for use in the field and in the laboratory. Official representatives of Belgium, Germany, Italy, Norway, Austria, Roumania, Russia and Hungary participated in this conference. The total number of delegates in attendance was approximately 100.

Among other things, it was decided at this conference to hold the Second International Conference in 1910 at Stockholm, Sweden. The then Swedish Minister of Agriculture was designated Honorary President of the Second Conference and the Secretary General of the Eleventh International Congress of Geology was chosen as the Presiding Officer. Representatives of Argentine, Belgium, Bulgaria, Denmark, Egypt, France, Germany, Great Britain, Holland, Italy, Japan, Mexico, Norway, Austria, Portugal, Russia, Sweden, Switzerland, Spain and Hungary, were present at this conference. There were altogether 170 participants in the meetings. The program of the conference was arranged in six sections, namely, (1) the mechanical analysis of soils; (2) soil colloids; (3) the preparation of soil extracts and their chemical analysis; (4) special investigations of soils; (5) classification, terminology and cartography of different types of soils; (6) soil conditions and problems in different countries. It was resolved to organize a committee on the status of soil investigations in different countries. A second committee was designated on the preparation of soil extracts for the purpose of chemical analysis and a third committee on soil terminology. It was further resolved to hold the Third International Conference at St. Petersburg, Russia, in 1914. Difficulties developed, however, which made it impossible to hold the Third Conference at St. Petersburg. Meanwhile an invitation had come from the Government in Italy to hold the Third Conference in Rome in 1914. The declaration of war prevented the accepting of this invitation.

The Third International Conference was held at Prague, Czechoslovakia, April 19–24, 1922, under the presidency of Prof. M. Kopecky. Fifty delegates, representing Denmark, The Netherlands, Norway, Sweden, Finland, Russia, Roumania, Jugoslavia, Poland, Hungary, Switzerland, Germany, Ukraine, Czechoslovakia and the United States of America, participated in the meetings. Our own country was represented by Prof. C. F. Marbut and the chairman of your committee. Communications expressing interest in the aims and activities of the conference were received from Austria, England, Ireland, Italy, Japan, Dantzig, South Africa, Egypt and France. The officers of the Third Conference were: Honorary President, Prof. Dr. E. Ramann, Munich; President, Prof. Dr. Joseph Kopecky, Prague; Vice-President, Dr. D. J. Hissink, Groningen; Secretary-Treasurer, Prof. Dr. F. Schucht, Berlin. The members of the General Committee included Prof. Dr. G. Murgoci, Bucharest; Prof. Dr. A. de Sigmond, Budapest; Prof. Doctor Peter Treitz, Budapest; Prof. Dr. A. Vesterberg, Stockholm and the chairman of your committee. The program of the conference was arranged under the following heads: (1) methods for the mechanical analysis of soils; (2) the physical examination of soils; (3) the chemical examination of soils; (4) soil acidity; (5) soil bacteriology; (6) soil cartography; (7) international publications on soils; (8) the organization of the fourth conference. Five committees were organized and made responsible for the program of the Fourth Conference. These committees were constituted as follows:

1. Committee on the mechanical and phyical analysis of soils. Chairman, Prof. Joseph Kopecky, Prague. A subsection on soil biology was also established. Chairman, Dr. M. I. Girsberger, Zurich.
2. Committee on the chemical analysis of soils. Prof. Dr. A. de Sigmond, Chairman.
3. A Committee on soil bacteriology, under the chairmanship of Prof. Dr. Julius Stoklasa, Prague and the chairman of your committee.
4. A Committee on Soil Nomenclature. Dr. Benjamin Frosterus, Helsingfors, Chairman.
5. Committee on Cartography. Prof. Dr. G. Murgoci, Bucharest, Chairman.

An invitation in behalf of the Italian Society of Agronomy was received from Dr. Borghesania, of the International Institute of Agriculture, to hold the Fourth Conference at Rome, Italy. It was decided to accept this invitation and to hold the Fourth Conference in Italy. Accordingly, the Fourth International Conference was held at the International Institute of Agriculture at Rome on May 12–19, 1924. The meetings, held under the patronage of His Majesty The King of Italy, were strikingly successful and were participated in by delegates from more than twenty countries. The organization of the International Committee was as follows. Honorary President, Prof. Dr. E. Ramann, Munich; Presidents—Prof. Dr. G. Anderson, Stockholm; Prof. Dr. J. Kopecky, Prague, and Prof. Dr. G. de Angelis d'Ossat, Perugia; General Secretary, Dir. Dr. D. J. Hissink, Groningen. Members: Dr. A Bruno, Paris; Prof. L. Cayoux, Paris; Dir. Dr. B. Frosterus, Helsingfors; Colonel J. Girsberger, Zurich; Prof. Dr. K. Glinka, Petrograd; Dr. F. Lohnis, Washington; Prof. C. F. Marbut, Washington; Prof. Dr. G. Murgoci, Bucharest; Dr. V. Novak, Brno; Prof. Dr. G. Rossi, Portici; Sir John Russell, Rothamsted; Prof. Dr. F. Schucht, Berlin; Prof. Dr. A. A. J. de Sigmond, Budapest, Prof. Dr. J. Stoklasa, Prague; Prof. Dr. J. Zavadii, Brno, and the chairman of your committee. The Italian Organization Committee was as follows: President, Prof. Dr. G. de Angelis d'Ossat, Perugia; Secretary-Treasurer, Prof. R. Peroti, Rome. Members: Dr. G. Borghesani, Rome; Ing. E. Clerici; Ing. C. Crema; Ing. H. Del. Pelo Pardi; Dr. A. de Dominicis, Portici; Prof. G. Gola, Padova; Prof. M Gortani, Pavia; Prof. G. Lo Priore, Modena; Prof. O. Marinelli, Firenze; Prof. A. Martelli, Firenze; Prof. A. Menozzi, Milan; Prof. V. Novarese, Rome; Prof. E. Pantanelli, Bari; Dr. U. Pratolongo, Milan; Prof. G. Rossi, Portici; Dr. J. M. Saulnier, Rome; Prof. A. Stella, Torino; Prof. G. Tommasi, Rome; Prof. P. Vinassa de Regny, Parma.

The delegates included representatives from Germany, Belgium, Denmark, Egypt, Spain, France, England, Ireland, Greece, Japan, Norway, The Netherlands, Poland, Rumania, Russia, Sweden, Czechoslovakia, Palestine, Switzerland, Hungary, Austria, Italy, Jugoslavia, Finland, Latvia, India, Canada, Cuba, Chile and the United States of America. The last-named country was represented by Messrs. R. V. Allison, R. M. Barnette, A. Itano, M. M. McCool, S. A. Waksman, C. F. Marbut and J. G. Lipman. A large number of papers were presented and much progress made in the interchange of ideas among the delegates from the different countries. The program of the conference was divided into six sections, namely: I, Subsection a,—the mechanical and physical study of soils; Subsection b—the application of soil science to soil amelioration; II, the chemical study of soils; III, bacteriological and biochemical study of soils; IV, nomenclature and classification of soils; V, soil cartography; VI, plant physiology and its relation to soil science.

The conference was officially opened in the forenoon of May 11th with a reception to the delegates and members of the Societa Agronomica Italiana on

the Pincian Hill. Regular sessions were held on Friday, May 11th, to Saturday, May 19th, inclusive. Receptions, entertainments, and excursions were made a part of the program. At different times, the delegates and members were guests of the Municipality of Rome, and of the Italian Minister of Agriculture. Excursions were made to the Alban Hills, Pontine Marshes and to the country around Naples.

The delegates organized an International Society of Soil Science, whose constitution is appended to this report. Your chairman was elected president of the newly organized international society. It was voted to hold the Fifth International Conference of Soil Science at Washington, D. C., in 1927. The conduct of the Internationale Mitteilungen für Bodenkunde, the official organ of the society, was entrusted to a board of editors consisting of Professors K. Glinda, D. J. Hissink, J. G. Lipman, G. Murgoci, E. Ramann and F. Schucht. Prof. Dr. F. Schucht, Berlin-Wilmersdorf, was elected editor-in-chief of the publication. Further information concerning the proposed organization of the Fifth International Conference may be found in the circular issued by Dr. D. J. Hissink for circulation in Holland. A copy of the translation of this circular is also appended to this report.

Since the American Society of Agronomy and the National Research Council have been officially represented in the Fourth International Conference of Soil Science, it would be well for the Society to lend its support toward the successful organization and conduct of the forthcoming conference. Your committee would recommend the following:

1. The appointment of an organization committee, which should have power to add to their members.
2. The organization of subcommittees on (a) program, (b)publicity, (c)transportation, (d) finance, (e) cooperation with other societies.
3. A committee on membership of the International Society of Soil Science should be appointed and entrusted with the responsibility of determining on a policy of coordinating the activities of the American Society of Agronomy, the Association of Soil Survey Workers and the International Society of Soil Science.

In behalf of the Committee the chairman wishes to submit herewith a report prepared by Dr. A. G. McCall on the activities of the Subcommittee on The Mineral Salt Requirement of Plants as well as of the Subcommittee on Sulphur Fellowships.

REPORT OF THE SUB-COMMITTEE ON MINERAL SALT REQUIREMENT OF PLANTS.

During the past year no new work has been inaugurated by this committee. Steps have been taken, however, toward the formulation of a report giving a brief account of the recent work with solution cultures and with sand cultures. A complete bibliography with brief summaries for each title has been prepared for the committee by Dr. R. P. Hibbard of the Michigan Agricultural College. It is expected that the Committee will have a complete and final report to present at the annual meeting of the Society in 1925.

A. G. McCall, *Chairman.*

REPORT OF THE COMMITTEE ON SULPHUR FELLOWSHIPS.

During the past two years work under the auspices of this committee has been in progress at the following institutions: University of California, Washington State Experiment Station, Kansas Agricultural College, University of Toronto, Ohio State University, Michigan Agricultural College, Clemson College, South Carolina, Florida Experiment Station, University of Pennsylvania, and the Uni-

versity of Maryland. During the present year, work has been discontinued at all of the institutions except that at the University of California and at the University of Maryland. The final results of these investigations will be published from time to time as experiment station bulletins or as journal articles.

The Texas Gulf Sulphur Company has approved the continuation of the study of the effect of sulphur on alkali soils at the University of California, and the study of the effect of sulphur on nematode infestations which is being conducted under the joint auspices of the University of Maryland and the U. S. Department of Agriculture.

A. G. McCall, *Chairman.*

APPENDIX

Constitution of the International Society of Soil Science.

1. The Society shall be called the "International Society of Soil Science."
2. The object of the Society is the study and promotion of soil science in general by means of:
   (a) the organization of Congresses and Conferences;
   (b) the formation of Sections and Committees;
   (c) the publication of a review;
   (d) the institution of a Central Office for Soil Science bibliography (documentation) at the International Institute of Agriculture at Rome.
4. The Fourth International Conference founds the International Society of Soil Science. Persons taking part in this Conference have the right to join the Society as foundation members. Any individual or body corporate engaged in the study of soil science is eligible for ordinary membership of the society. The names of new members must be proposed by two members and will be published in the review.
6. For particular countries sections may be formed within the Society either for the study of soil science in general or for the study of certain aspects of the subject.
   Every Section consisting of more than 15 members has the right to be represented on the General Committee by one member.
7. The Society carries out its work through the following bodies:
   (a) the Executive Committee (Bureau).
   (b) the General Committee.
   (c) the Sub-Committees.
8. . . . .
   The duties of the General Secretary may be discharged by one of the other members of the Executive Committee. . . . .
11. The Congress is under the General patronage of the International Institute of Agriculture in Rome.
13. The scientific work of the Congress consists in the presentation of reports, discussions, demonstrations, and where desirable in the arrangement of exhibitions.
14. The Review is published by the Executive Committee under the direction of the editor. The printing and publication is undertaken by the International Institute of Agriculture in Rome. It will appear in separate numbers forming an annual volume beginning with January 1, 1925. It is a purely scientific review for original work on general soil science.
    It also serves the following purposes:
    (a) The establishment of as full a conspectus as possible of the most recent publications concerning soil science as a whole and kindred subjects.
    (b) Abstracts of the most important of the recent publications.
    (c) Publication of information relating to the activities of the Society in English, French, German, Italian and Spanish.
15. The Executive Committee will supply the editor with the staff and means to carry out his work. The Sections and Sub-Committees appoint their own assistants, whose business it is to collect the documentation and to publish information relating to the Society so far as it relates to the special work of the Section or Sub-Committee.

16. The members of the Society are entitled to receive the Review gratuitously after payment of their annual subscription.
17. The funds of the Society are provided as follows:
    (a) by the annual subscription of members; the amount to be fixed each year by the Executive Committee;
    (b) by the amounts of the subscriptions to the Review and advertisements charges, as well as by the sale of reprints and special publications;
    (c) by voluntary contributions.

INTERNATIONAL SOCIETY OF SOIL SCIENCE

In May 1924, the fourth Congress of Soil Science took place in Rome with the participation of numerous scientists from nearly all nations of the world. In its last meeting—Monday 19th of May—the Congress decided to create an International Society of Soil Science. The undersigned have the honor to inform you that they have joined this Society as regular members. All details concerning the aim of the Society, the constitution of its Board and the contributions for 1924 will be found in the Appendix below:

We advise you to become a member of the Association. If the number of Dutch members happens to be large enough, it is our plan to organize a special branch for Holland.

Prof. J. van Baren........................Wageningen
Eng. W. G. Bijl.........................Hoofddorp
Dr. F G. Gerretsen.......................Groningen
Dr. D. J. Hissink........................Groningen
Eng. J. F. Lightenberg...................Den Haag
Eng. C. E. W. Van Zanhuys................Den Haag
Dr. I. Can der Spek......................Groningen
Dr. P. Tesch.............................Haarlem
Dr. K. Zijlstra..........................Groningen

APPENDIX

The aims of the Society of Soil Science are:
(1) The organization of Congresses and Meetings;
(2) The organization of Sections and Committees for the study of special subjects;
(3) The publication of a Journal;
(4) The institution of a central service of documentation by the International Institute of Agriculture of Rome.

The Society will have its headquarters in Rome. Local branches can be organized in each country; these branches have the right to appoint a representative to the Society.

The next Soil Congress will be held in America—"Die Internationale Mitteilungen fur Bodenkunde" will remain the official organ of the Society with Prof. Schucht as editor. The service of documentation will be placed in the hands of Dr. Borghesani and located in the building of the International Institute of Agriculture.

ADMINISTRATION OF THE SOCIETY SEAT IN ROME

Honorary Committee—Prof. Dr. E. Ramann, Munich; Prof. Dr. L. Cayeuk, Paris; Prof. Dr. G. Glinka, Petrograd; Prof. Josef Kopecky, Prague; Prof. Dr. G. Hurgoci, Bucarest; Sir. J. E. R. Russell, D.Sc., F.R.S., Rothamsted, Harpenden; Prof. Dr. Winogradsky, Russia.

Executive Committee—Prof. Dr. Jacob G. Lipman, New Brunswick, (U. S. A.), chairman; Dr. D. J. Hissink, Groningen, assistant chairman; Prof. G. de Angelis d'Ossat, Rome; Dr. Benh. Frosterus, Helsingfors, vice-chairman; a member appointed by the International Institute of Agriculture of Rome. Dr. D. J. Hissink, Groningen, Secretary General; Prof. Dr. F. Schucht, Editor of the Journal; Dr. G. Borghesani, Rome, librarian.

General Board—Prof. Andre, Paris; Prof. Kso, Tokyo; Dr. Christensen, Copenhagen; Prof. Hesselman, Stockholm; Dr. Hiklazewski, Varsaw; Prof. Novarsee, Rome; Dr. Novack, Brunn; Prof. von Sigmond, Budapest; Prof. Stoklasa,

Prague; Prof. Mitscherlich, Konigsberg; Prof. Harbut, Washington; Ing. Girsberger, Zürich.

The last six members have their place in the General Board as chairmen of the following committees;

(1) mechanical and physical soil survey; (2) chemical soil survey; (3) bacteriological soil survey; (4) soil survey in relation to plant nutrition; nomenclature, classification, cartography; (6) soil survey in relation to cultivation (soil preparation).

Controllers—Prof. Dr. R. Perotti, Rome; Dr. K. Zijlstra, Groningen, a member from America to be appointed by Dr. Lipman.

The members agree to contribute for 1924 a sum of at least two dollars to be sent to the General Secretary (Dr. D. J. Hissink, Herman Colleniusstraat 25, Groningen). In view of the establishment of a fund, all higher contributions will be welcomed. It is hope that financially strong Institutions and Companies will make a special effort to support the fund.

The contribution for 1925 will be determined later. But it can already be stated that it will be hardly more than two dollars. The members will receive the Journal gratis beginning January 1, 1925.

It was moved and carried that the incoming Executive Committee in consultation with the President of the Congress immediately appoint a committee to assist in making necessary arrangements for the International Congress of Soil Science to be held in Washington, D. C., in 1927.

Prof. J. F. Cox reported for the Committee on Intercollegiate Grain Judging Contests, giving a brief statement of the contest held. The report follows:

REPORT OF THE COMMITTEE ON INTERCOLLEGIATE CROPS JUDGING CONTEST.

The first intercollegiate crops contest was held in Chicago, December 6, 1923, in connection with the Hay and Grain Show of the International Livestock Exposition. Considerable difficulty was experienced in securing a suitable place to hold the contest, which made it impossible to begin on schedule time. This difficulty will not be encountered in staging future contests. Teams from seven agricultural colleges participated in the contest.

This year the contest will be held Saturday, November 29. The crops contest needs the same financial backing as is given the livestock contest and it is the aim of the committee to bring this about during the year if possible.

A. C. ARNY,
C. A. HELM,
S. C. SALMON, *Committee.*

Dr. C. R. Ball, the representative of the Society on the joint committee with the phytopathologists, on the Terminology of Physiologic Entities in Fungi, presented the following report which was accepted:

REPORT OF COMMITTEE OF THE AMERICAN SOCIETY OF AGRONOMY ON TERMINOLOGY OF CERTAIN FUNGOUS ENTITIES.

The undersigned were the representatives of this Society on a joint committee which had representatives also from the Phytopathological Society and the Mycological Section of the Botanical Society of America. Dr. C. L. Shear was a representative from each of the three societies on this joint committee, the other member from the Phytopathological Society being Dr. E. C. Stakman and the second member from the Mycological Section being Dr. H S. Jackson. A meeting was held in Washington in midsummer at which Dr. Stakman and the two representatives of this Society were present. At this meeting the following agreements were reached:

1. The word "physiologic" or "physiological" is to be used instead of "biologic" or "specialized" for those forms, races or strains of fungi

which are differentiated by physiological means such as inoculations on a series of differential hosts.

2. The use of the word "form" in connection with fungi shall be restricted to physiological entities, and it shall not be used to designate entities separable primarily by morphological characters.
3. The term "physioform" to denote forms recognized by physiological action was suggested, but no action was taken pending further consideration.

Dr. Jackson later approved the recommendation of the committee for the use of the word "physiologic." He also approved the use of the word "form" rather than "race" or "strain." He further records himself as being in favor of the term "physioform."

Respectfully submitted,
C. R. BALL,
C. L. SHEAR, *Committee.*

The revisions of the Constitution as proposed at the last annual meeting of the Society were read by the Secretary and each article was separately adopted. The revised Articles IV, VI, VIa and VII were given in the minutes of the sixteenth annual meeting published in Volume 15, No. 12, of the JOURNAL.

The Secretary reported for the EXECUTIVE COMMITTEE, recommending that a Southern Section of the Society be formed, that the American Soil Survey Association and the Western Canadian Society of Agronomy be invited to affiliate. The report was adopted.

It was moved and carried that the new Executive Committee appoint a committee to cooperate in the organization of the proposed International Congress of Plant Sciences.

Dr. M. J. Funchess reported for the AUDITING COMMITTEE that the books of the Treasurer had been examined and found to be well-kept and correct. The report was adopted.

The report of the Committee on RESOLUTIONS was given by the Chairman, Dr. C. E. Leighty, as follows:

I. *Resolved:* That the thanks of the Society be extended to the management of the New Ebbitt Hotel for the facilities provided for the seventeenth annual meeting.

II. *Resolved:* That the Society express its thanks to the leaders of the symposia, Prof. E. G. Montgomery, Dr. K. F. Kellerman, Prof. H. R. Sumner, Dr. W. L. Burlison, and Prof. Emil Truog, for their painstaking efforts in arranging the several programs.

III. *Resolved:* That the thanks of the Society be extended to its Secretary, P. E. Brown, its President, Prof. M. F. Miller, and its Editor, Dr. R. W. Thatcher, for their painstaking and efficient work (during the past year, in behalf of the Society) and to Dr. R. A. Oakley for arranging the details for the meeting in Washington.

IV. *Resolved:* That the Society express its deep sense of bereavement in the loss of our beloved Secretary of Agriculture, the Honorable H. C. Wallace, and that we extend to Mrs. Wallace and the other members of the family our deepest sympathy in their great sorrow.

C. E. LEIGHTY,
EMIL TRUOG, *Committee.*

The report of the Committee was adopted.

Director S. B. Haskell, Chairman, presented the following report of the NOMINATING COMMITTEE.

President—C. W. Warburton, 1st Vice-Pres.—A. G. McCall, 2nd Vice-Pres.—W. L. Burlison, 3rd Vice-Pres.—M. J. Funchess, 4th Vice-Pres.—E. F. Gaines,

Representative on the National Research Council for 5 years—R. A. Oakley, Representatives on the A. A. A. S. Council—L. E. Call and Emil Truog, Representatives on the Council of the Biological Union—R.W. Thatcher and F.E. Bear.

It was moved and carried that the report of the Committee be adopted and the Secretary cast a unanimous vote for the officers nominated. The vote was cast and the officers declared elected.

The President-elect, Prof. C. W. Warburton, was called on and responded with brief remarks in which he thanked the Society for the honor conferred upon him and pledged his best efforts to the furtherance of the interests of the Society.

The meeting then adjourned.

MORNING SESSION, TUESDAY, NOVEMBER 11.

The program on Tuesday was in two sections, one on Soils and one on Field Crops.

The Soils program consisted of a symposium on "Soil Colloids" arranged by Prof. Emil Truog and the following papers were given:

1. "The Chemical Nature of Soil Colloids."
   Dr. Richard Bradfield, University of Missouri.
   Discussion: Drs. M. S. Anderson, Sante E. Mattson and W. O. Robinson, Bureau of Soils, U. S. D. A.; Dr. F. W. Parker, Alabama Agricultural College.
2. (a) "The Colloidal Content of Soils."
   Dr. P. L. Gile, Bureau of Soils, U. S. D. A.
   (b) "The Colloidal Determination in Mechanical Analysis."
   Dr. R. O. E. Davis, Bureau of Soils, U. S. D. A.
   Discussion: Dr. A. B. Beaumont, Massachusetts Agricultural College; Dr. Richard Bradfield, University of Missouri.
3. "The Significance of Soil Colloids, Especially in Relation to Plant Feeding, and Leaching and Fixation of Essential Elements."
   Prof. Emil Truog, University of Wisconsin.
   Discussion: Drs. A. G. McCall and N. E. Gordon, University of Maryland; Dr. B. L. Hartwell, Rhode Island Agricultural College; Dr. C. S. Scofield, Bureau of Plant Industry, U. S. D. A.
4. "The Effect of the Colloidal Content on the Physical Properties of Soils."
   Dr. George Bouyoucos, Michigan Agricultural College.
   Discussion: Drs. R. O. E. Davis and H. E. Middleton, Bureau of Soils, U. S. D. A.
5. "Climatic Agencies in Relation to Soil Colloids."
   Prof. R. M. Salter, Ohio State University.
   Discussion: Prof. S. D. Conner, Purdue University.

The Field Crop program was on "The Legume Problem" and was under the leadership of Prof. H. R. Sumner. The following papers were read:

1. "The Economics of Increased Legume Production."
   Dr. R. A. Oakley, Bureau of Plant Industry, U. S. D. A.
2. "The Utilization of Legumes in the Rotation."
   a. In the East
      Prof. John H. Barron, Cornell University.
   b. In the Middlewest
      Prof. Ralph Kenney, University of Kentucky.
   c. In the Northern Great Plains
      Prof. A. J. Ogaard, Montana State College.

d. In the South

Dr. M. J. Funchess, Alabama Agricultural College.

3. "The Function of Annual Legumes."

Prof. E. E. Barnes, Ohio State University.

4. "The Future of Sweet Clover in the Corn Belt."

Prof. H. D. Hughes, Iowa State College.

5. "The Inter-dependency of a Legume Program with Other Agricultural Projects in Extension Work."

Prof. O. S. Fisher, Agricultural Extension Division, U. S. D. A.

6. "A State Wide Campaign for More Legumes."

Prof. P. F. Schowengerdt and Prof. C. E. Carter, University of Missouri.

Afternoon Session, Tuesday, November 11.

The afternoon program of the Soils Section consisted of a symposium on "Nitrogen Fixation" arranged by Dr. K. F. Kellerman. The following papers were given:

1. "Chemical Nitrogen Fixation."

Dr. F. G. Cottrell, Fixed Nitrogen Laboratory, Washington, D. C.

2. "Bacterial Nitrogen Fixation."

Dr. F. Löhnis, Bureau of Plant Industry, U. S. D. A.

3. "Nitrogen Fixation under Field Conditions."

Dr. J. G. Lipman, New Jersey Agr. Expt. Sta.

4. "Soil Inoculation with Azotobacter."

Dr. P. E. Brown, Iowa State College.

5. "Recent Results of Inoculation, Especially with Garden Peas for Canning."

Dr. A. L. Whiting, University of Wisconsin.

The program in the Field Crops Section was on "Plant Physiology and Agronomic Science" arranged by Dr. W. L. Burlison. The following papers were presented:

1. "Why Agronomy Needs Research in Plant Physiology."

Dr. Carleton R. Ball, Bureau of Plant Industry, U. S. D. A.

2. "The Desirability of a Knowledge of the Storage and Utilization of Organic Reserves in Crop Production."

Dr. E. J. Kraus, University of Wisconsin.

3. "The Relation of Plant Physiology and Chemistry to the Study of Disease Resistance in Plants."

Dr. James G. Dickson, University of Wisconsin.

4. "What Contributions of Plant Physiology will Most Benefit the Agronomist."

Dr. Charles F. Hottes, University of Illinois.

5. "Points of Agronomic Interest in the Physiology of Germination."

Dr. Wm. Crocker, Boyce-Thompson Institute.

6. "Soil Moisture in Relation to the Growth of Crop Plants."

Dr. H. L. Shantz, Bureau of Plant Industry, U. S. D. A.

7. "Hydrogen-ion Concentration of the Soil Moisture with Reference to Plant Growth."

Dr. Lewis Knudson, Cornell University.

The entire meeting was most successful and enjoyable. One hundred and eighty registered, and a considerable number who did not register attended some of the sessions. The total attendance was over 200.

P. E. Brown, *Secretary.*

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